

A Spotlight on Topographic Maps in the Baltic Sea Region and Their Path to International Harmonisation

Introduction

During early modern times, some of the greatest and most relevant achievements of cartography occurred in the Baltic Sea region, including outstanding map products like the *Geometrisk upmätning av Pommern 1692–1709* (the Swedish land survey in Pomerania 1692–1709)¹ or geodetic experiments like the *Struve Geodetic Arc*.² Nevertheless, the region marks a typical example of the manifold fragmentations of topographic maps that lasted from the beginning of modern cartography in the 17th century until recent international harmonisation efforts and the availability of satellite-based information for positioning and land cover mapping.

Topographic maps are two-dimensional representations of a land area, representing the location or extent of both natural and human-made features as well as the underlying terrain. From the late 18th century onwards, the production of topographic maps—understood in the sense of systematic, large-scale national cartographic surveys—was primarily carried out by governmental agencies, both military and civilian. These mapping efforts served various purposes, notably military planning as well as fiscal administration.

The aim of this chapter is to highlight topographic maps as an example for the long paths from fragmentation to harmonisation. First, we outline selected important steps along this path from a technical and historical perspective in the context of the Baltic Sea region and Germany in particular. Then, we showcase this development as represented in relevant, historic topographic map products from the Baltic Sea region. We conclude with a look at state-of-the-art provision of historic topographic maps on online geoportals.

1 Baier, Rudolf: Geschichte der Communalstände von Neuorpommern und Rügen. Mit einem Rückblicke auf die ständische Verfassung und Verwaltung der früheren Jahrhunderte, Stralsund 1881, p. 27.

2 UNESCO Word Heritage Convention: Struve Geodetic Arc, whc.unesco.org/en/list/1187/ (30.07.2025).

National and International Harmonisation in Cartography until the Late 19th Century

Technological Progress, International Knowledge Transfer and National Standardisation

Some of the earliest systematic land surveys and map productions were conducted since the second half of the 17th century on Swedish territories, including Livland (today located in Latvia and Estonia) as well as Western-Pomerania (today located in Germany and Poland),³ which were under Swedish control at that time. Although these maps are no map series in the modern sense, they were created with modern techniques employed in all modern map series in the following centuries. But not only that: contrary to the usual practices in European history, where maps were produced by private entities, the Swedish Crown established an education system for land surveyors, issued instructions on which landscape features had to be systematically documented and how they were to be represented on the maps, and sent them to the areas to be mapped on the orders of the government.⁴

In the 17th and 18th centuries, France became the leading nation in geodesy and land surveying, largely due to the work of the *Académie des Sciences*, founded in Paris in 1666. The geodetic framework for this was established by Abbé Jean Picard in 1669/1670. Based on a degree measurement along the Paris meridian using triangulation, he determined the Earth's radius with remarkable precision—even though he still assumed the Earth to be a perfect sphere.⁵ An expedition to Lapland in 1736⁶ is regarded as one of the first international geodetic missions⁷ and produced the first accurate data on

3 Drolshagen, Carl: Die schwedische Landesaufnahme und Hufenmatrikel von Vorpommern als ältester deutscher Kataster I. Beiheft zum 17./38. Jahresbericht der Geographischen Gesellschaft Greifswald, Greifswald 1920; id.: Die schwedische Landesaufnahme und Hufenmatrikel von Vorpommern als ältester deutscher Kataster II. Beiheft zum 40./41. Jahresbericht der Geographischen Gesellschaft Greifswald, Greifswald 1923.

4 Ekstrand, Victor: Samlingar i Landtmäteri—Första samlingen Instruktioner och Bref 1628–1699, Landtmäteri-Kontoret, Stockholm 1901.

5 Torge, Wolfgang: Geschichte der Geodäsie in Deutschland, Berlin/New York 2009, p. 61.

6 Outhier, Reginald: Journal d'un voyage au nord, en 1736. & 1737, Paris 1744.

7 de Maupertius/Camus/Clairaut/le Monnier/Outhier/Celsius: The Figure of the Earth, Determined from Observations Made by Order of the French King, at the Polar Circle, London 1738.

the flattening of the Earth in 1737.⁸ Starting in 1733 under César-François Cassini de Thury (Cassini III), the initial meridian chain was expanded into a nationwide triangulation, which served as the geometric basis for the *Carte géométrique de la France* (1751–1793), produced at a scale of 1:86,400. This was the first topographic and geometric survey of an entire country.⁹ French developments had a significant influence on geodetic practices in other countries. The *École royale du génie* in Mézières, founded in 1748, trained not only French military engineers in surveying and cartography but also officers from Sweden, Russia, and Prussia.¹⁰

The Napoleonic period (1799–1815) also had a major impact on geodesy in the German territories, as Napoleon considered accurate topographic maps essential for military operations. French engineer-geographers carried out systematic triangulation-based surveys in both occupied and allied areas. One example is the survey of the Rhineland,¹¹ which was integrated into the French system.¹² By the late 18th century, several German principalities began their own systematic national surveys. In Saxony, triangulation-based large-scale mapping was initiated in a project from 1780 onward.¹³ In Oldenburg, triangulation was conducted between 1782 and 1798¹⁴ in connection with the Danish network. Other surveys, such as the *Kurhannoversche Landesaufnahme* (1764–1786), still operated at the technical level of the earlier Swedish land survey, relying primarily on plane-table triangulation and lacking a trigonometric framework.

8 Puziene, Ruta: The Struve Geodetic Arc: the development of the triangulation, technical possibilities, and the initiation of the project, in: *History of Geo- and Space Sciences* 10 (2019), No. 2, pp. 269–277, 2019, DOI: 10.5194/hgss-10-269-2019.

9 *ibid.*, p. 273.

10 Dupuit, Jules: Notice sur l'École royale du génie de Mézières (1748–1794), in: *Annales des Ponts et Chaussées* 1862, p. 237 and p. 241.

11 The survey was conducted by Colonel Jean Joseph Tranchot (1752*–1815†, isni.org/isni/0000000083533224) between 1801–1814.

12 Torge, Wolfgang: Der lange Weg der preußischen Landesvermessung: zum 100. Todestag von Oscar Schreiber (1829–1905), in: *ZfV—Zeitschrift für Geodäsie, Geoinformation und Landmanagement* 130 (2005), No. 6, pp. 359–371: p. 360.

13 »Meilenblätter von Sachsen«, Friedrich Ludwig Aster (1732*–1804†, isni.org/isni/000000007830702X).

14 The triangulation was conducted by Georg Christian von Oeder (1728*–1791†, isni.org/isni/0000000122766275).

The Swedish land survey in Pomerania 1692–1709

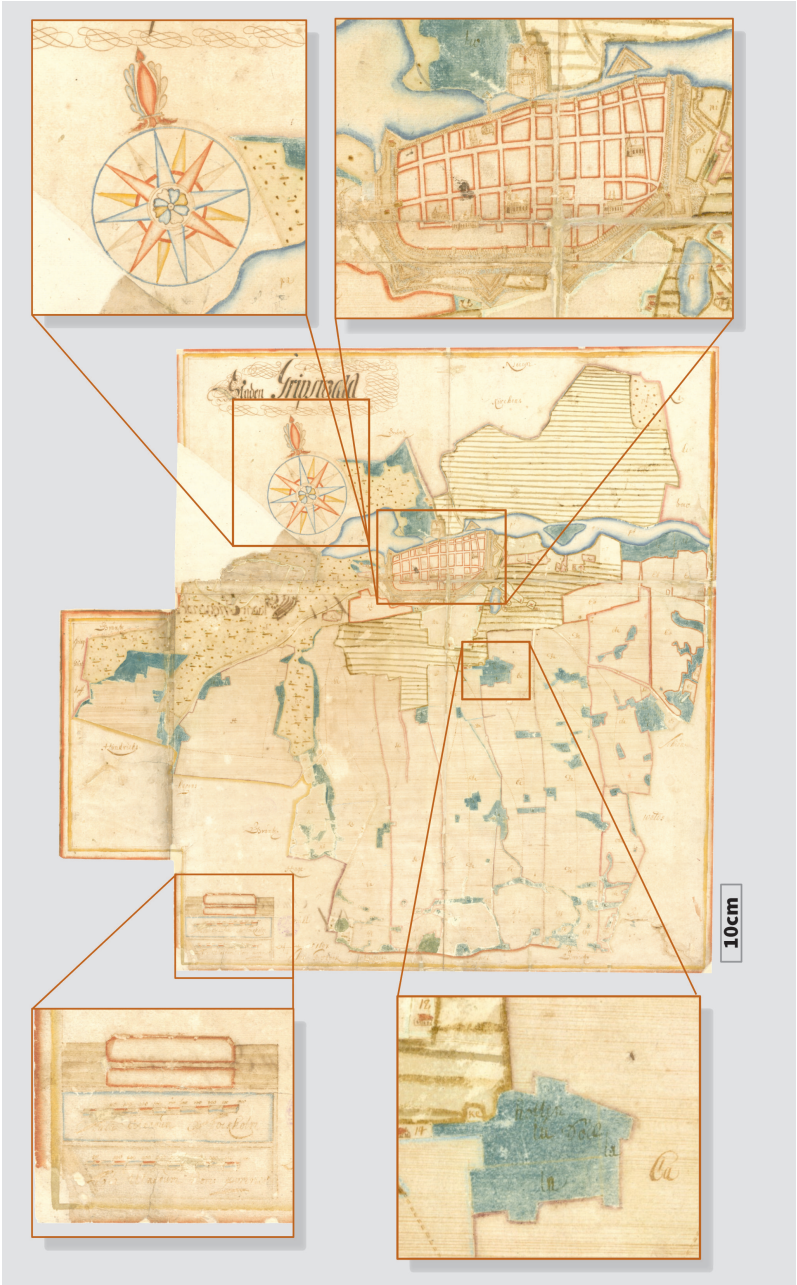
From 1648 to 1815, between the Thirty Years' War and the Congress of Vienna^[1], parts of Pomerania were under Swedish control^[2]. The Swedish Land Survey was initiated under King Charles XI of Sweden (r. 1660–1697) and continued under his successor, King Charles XII (r. 1697–1718). It aimed to systematically record property ownership, the estimated revenue potential of the land, and topographical features in order to improve administrative efficiency and fiscal control. The project was conceptually and organisationally shaped by Carl Gripenhielm (1655–1694), Director of the Swedish Land Survey Office, while field operations in Pomerania were directed by Gunno Eurelius Dahlstierna (1661–1709), who served as inspector of the surveying commission.

The Pomeranian survey is regarded as one of the earliest large-scale cadastral enterprises in Europe, employing triangulation methods. The result was hundreds of maps and accompanying texts, which to this day represent a valuable source for research into early modern settlement structures, land use and socio-economic aspects.

The example shows the map of Greifswald, depicting the city in the upper central part of the image, the Ryck River — shown as the blue-outlined area — flowing from the right side and ending in wetlands in the left section, and extensive fields in the remaining area, accompanied by small meadows indicated by a dark green colour. Forest or woodland is absent. Orientation is provided by a decorative compass rose, and the map scale is presented in a cartouche with scale bars showing distances in Swedish ell and Pomeranian ell.

[1] *As a result of the agreements made at the Congress of Vienna in 1815, Sweden lost its territories in Pomerania.: Klüber, J.L.: Acten des Wiener Congresses in den Jahren 1814 und 1815 - Neunter Band. Hrsg. von Johann Ludwig Klüber. Erlangen, J. J. Palm und Ernst Enke, 1835. S. 275-285,347*

[2] *Since the Peace of Westphalia in 1648, the southern Baltic territories (including Western Pomerania, Wismar, and Bremen-Verden) were legally part of Sweden. Following military defeats in the Great Northern War, Sweden lost most of these possessions. Wismar remained formally under Swedish sovereignty until 1903, although it was pledged to Mecklenburg-Schwerin in 1803 and effectively left Swedish control from that point on.*



Following the Napoleonic Wars, the Prussian geodetic program under Freiherr von Müffling¹⁵ took the French model as its point of reference. The aim was a unified national survey with a trigonometric foundation, connected with the French meridian measurements. Between 1820 and 1876, the *Preußische Urmesstischblätter* at a scale of 1:25,000 were produced—hand-drawn originals intended as base material for later, smaller-scale map series, such as the *Topographische Karte vom Preußischen Staate 1:100,000* (from 1831), a predecessor of the *Karte des Deutschen Reiches 1:100,000*.¹⁶

From 1832 to 1835, Friedrich Wilhelm Bessel¹⁷ and Prussian Lieutenant General Johann Jacob Baeyer¹⁸ conducted a meridian arc measurement in East Prussia, completing Müffling's triangulation and linking it to Russian networks. The coastal survey (1837–1842) and the Danish connection (1839–1841) further extended the network across the Elbe.¹⁹ In contrast to the predominantly nation-state-oriented political thinking of the time, this clearly demonstrates that the goals within the geodetic professional community were more strongly aligned with transnational thinking.

The demand for standardisation was intensified as part of the unification of Germany in 1871. This led to the introduction of the metre as the official unit of length in Germany (1870/1872),²⁰ replacing a wide range of traditional units²¹ and creating a uniform system of measurement across the new nation-state. This step was closely connected to the recommendations of the *Mitteuropäische Gradmessung* (Central European Arc Measurement) from 1862, an international scientific initiative founded by Baeyer.²² In addition, the *Metre Convention* was signed in Paris in 1875 by 17 nations, including the

15 Friedrich Carl Ferdinand Freiherr von Müffling (1775*–1851†); Gothaisches genealogisches Taschenbuch der freiherrlichen Häuser. Vier und dreißigster Jahrgang, Gotha 1884, p. 579.

16 Staatsbibliothek Berlin: Frühe Landesaufnahmen Preußens und anderer Länder. Quellen und Highlights für die Forschung, kartenhighlights.staatsbibliothek-berlin.de/fruehe-landesaufnahmen-preussens-und-anderer-laender/ (30.07.2025).

17 1784*–1846†, isni.org/isni/0000000108797331.

18 1794*–1885†, isni.org/isni/0000000109046724.

19 Torge: Der lange Weg der preußischen Landesvermessung, p. 362.

20 Proebst, Max: Die Verfassung des Deutschen Reichs vom 16. April 1871 nebst verfassungsrechtlichen Nebengesetzen, Verträgen u. mit Anmerkungen und Sachregister, Nördlingen 1885, p. 27.

21 Boehn, Hubert von: Generalstabsgeschäfte: ein Handbuch für Offiziere aller Waffen, Potsdam 1862, pp. 255–258.

22 Baeyer, Johann Jacob: General-Bericht über den Stand der mitteleuropäischen Gradmessung Ende 1862, Berlin 1862.

Baltic Sea region states of Germany, Denmark, Sweden and Norway, as well as Russia.²³

Despite the high quality of the survey and map production and the trend towards harmonisation of maps as part of movements for national unification, topographic maps still marked a geographically limited endeavour. In 1861, Baeyer suggested the consolidation of all national geodetic triangulation networks into a unified European triangulation network.²⁴ This proposal²⁵ was accepted and ordered by King William of Prussia in the same year.²⁶ One year later, all major German states, such as Bavaria, Saxony, and Hanover, along with nine international countries, including Belgium, Italy, Austria, and Norway, joined this amicable project.

Harmonisation through International Collaboration

More critical was the harmonisation of the geographic coordinate system. While the equator provided a logical reference for defining 0° latitude, agreeing on a prime meridian (0° longitude) proved to be far more complicated (see Table 1). For example, Sweden based its central meridian on the longitude of the Stockholm Observatory, Russia used Pulkovo Observatory, and Prussian (later German) maps referenced Ferro, referring to the Spanish Canarian Island of El Hierro. Although the Ferro meridian had already been in use since the time of Ptolemy, it was Cardinal Richelieu²⁷ who, in 1634, formally adopted it as the reference meridian for France and promoted it as a standard for the broader civilised world.²⁸ It marks the western edge of the ancient Old World and was therefore a useful prime meridian in coordinate systems designed to assign positive values to locations east of it. Maps and the coordinates measured on different prime meridians were hardly, or sometimes simply not, comparable

23 Ris, Friedrich: Zur Geschichte des internationalen Mass- und Gewichtsbüreau's und der neuen Prototype des Meters und des Kilogramms, Bern 1890, pp. 27–29.

24 Baeyer, Johann Jacob: Über die Größe und Figur der Erde. Eine Denkschrift zur Begründung einer mittel-europäischen Gradmessung nebst einer Übersichtskarte, Berlin 1861, p. III.

25 Engel, Ernst: Die mitteleuropäische Gradmessung und die erste allgemeine Conferenz der von den Regierungen der beteiligten Staaten dazu Bevollmächtigten in Berlin vom 15. bis 22. October 1864, in: Zeitschrift des Königlich Preussischen statistischen Bureaus. Band 4, 1864, p. 238.

26 Baeyer, Johann Jacob: Zur Entstehungsgeschichte der europäischen Gradmessung, Berlin 1862], p. 6, urn:nbn:de:bvb:12-bsb10053757–8.

27 Armand-Jean du Plessis, duc de Richelieu (1585*–1642†, [isni.org/isni/00000000069180450](https://www.isni.org/isni/00000000069180450)).

28 Figueras y Pey, D. Josè: Lecciones de geografia astronómica, física y política, Barcelona 1848, p. 51.

between various regions in Europe. This changed fundamentally with the adoption of a common prime meridian. In 1884, delegates from 26 countries, including Germany, Denmark, Sweden–Norway, and Russia, met at the International Meridian Conference in Washington D.C.²⁹ and established the *prime meridian*, passing through the Greenwich Observatory in the United Kingdom, as the initial longitude to be used in a global system of plus/minus 180 degrees to the east and west, respectively. This decision marked a milestone in the harmonisation of European cartography after centuries of fragmentation.

From a technical perspective, the path to more harmonised cartography not only included international agreements and conventions, but also innovation and pioneers of engineering. In particular, there was great uncertainty about the shape of the Earth for a long time. Therefore, French expeditions to Peru and Lapland, also in the second half of the 18th century, were needed to finally prove that the Earth was not a perfect sphere but an ellipsoid that is flattened at the poles.³⁰ While the flattening could be shown, its factor was only vaguely defined. Following this, the Baltic Sea region was home for one of the key advancements towards a more precise description of the ellipsoid. From 1816 to 1852, a multinational project between Russia, Sweden and Norway was performed:³¹ the *Struve Geodetic Arc*³² (Box 2). The resulting estimate of the Earth's radius at the equator deviated only ~160 m from today's satellite-based estimates³³ and the degree of flattening was estimated to be about 0.3393 % (1/294.73) of the Earth radius instead of ~0.3353 % (1/298.26), as estimated by satellite geodesy today.³⁴

29 U.S. Department of State: International Conference Held at Washington for the Purpose of Fixing a Prime Meridian and a Universal Day. October 1884. Protocols of the Proceedings, Washington D.C. 1884.

30 Biot, M.: XIX. Observation relating to the operations determine the Figure of the Earth, in: The Philosophical Magazine 52 (1818), No. 244, pp. 119–131: p. 122, <https://doi.org/10.1080/14786441808652017>.

31 Ersch, J. S./Gruber, J. G.: Allgemeine Encyclopädie der Wissenschaften und Künste in alphabetischer Folge von genannten Schriftstellern bearbeitet und herausgegeben von J. S. Ersch und J. G. Gruber. Mit kupfernen Charten. Erste Section A–G. Siebenundsiebzigster Theil. GRAAGAAS–GRADISCA, Leipzig 1864, p. 21.

32 Petermann, A.: Die Grosse Russisch-Skandinavische Breitengrad-Messung zwischen der Donau-Mündung und dem Nordende Europa's, in: Mittheilungen aus Justus Perthes' Geographischer Anstalt über wichtige neue Erforschungen auf dem Gesamtgebiete der Geographie von Dr A. Petermann, Gotha 1857, pp. 315–321.

33 »a = 6378137 m semimajor axis«; Moritz, H.: Geodetic reference system 1980, in: Bulletin Géodésique 54 (1980), pp. 395–405: p. 402, DOI: 10.1007/BF02521480.

34 »Im = 0,5130741 Toisen«; Rüdigisch, Robert von: Instrumente und Operationen der niederen Vermessungskunst, Cassel 1875, p. 9; »le demi grand-axe de la Terre a = 3272539 toises«; Struve, F. G. W.: Arc du méridien de 25°20' entre le Danube et la Mer Glaciale, mesuré depuis 1816 jusqu'en 1855, St.-Pétersbourg 1860, p. 84.

By the end of the 19th century, the technical basis and first formal international agreements had been established, yet the path towards fully harmonised topographic maps was still long.

The Struve Geodetic Arc



The Struve Geodetic Arc is a geodetic experiment across nowadays ten countries of the Baltic Sea Region. Starting in Fuglenes now district of Hammerfest, Norway, it stretches over 2820 km to Ismajil, Ukraine, at the Black Sea along 26° East (+/- 3°). The precise bearing of locations approximately along a single meridian are basis for estimating the exact size of the Earth and degree at which it is flattened at the poles. Initiated and led by the two astronomers and geodesists Friedrich G. W. Struve, working at Dorpat University (today Tartu, Estonia) and Carl Tenner, one of the founders of Russian geodesy, 265 survey points were precisely triangulated between 1816 and 1855 creating an arc of triangles spanning more than 25° latitude. The Struve Arc marked the longest experiment of its kind by that time and led to estimates that only slightly deviate from today's satellite based measurements. The Struve Geodetic Arc is a World Heritage Site and, beside others, two monuments mark the endpoints in Fuglenes and Stará Nekrasivka.

Source (modified): Struve Geodetic Arc-zoom-en.svg, (2022, June 30), Wikimedia Commons, Retrieved August 7, 2025, from https://commons.wikimedia.org/w/index.php?title=File:Struve_Geodetic_Arc-zoom-en.svg&oldid=669950798, ©CC BY-SA 4.0
 photos: Fuglenes by Vesna Vujcic-Lugassy, ©CC BY-SA 3.0 IGO ©UNESCO
 Stará Nekrasivka by VileGecko, ©CC BY-SA 4.0

Phases of Harmonisation and Fragmentation in the 20th Century

First Approaches to Pan-European Cooperation in the Early 20th Century

By 1900, the entire Baltic Sea region was comprehensively mapped, albeit through a mosaic of national map series (see Figure 1). The national systems still varied in the selection of landscape features, symbolism, scales, underlying coordinate systems, and geodetic projections (Table 1). Distance and area estimates across map products were impossible, as most maps were based on national coordinate reference systems, which were most accurate in the respective national centres and increasingly distorted towards the border regions. Geodesists across Europe recognised the need to link national triangulation networks across borders to establish a scientifically robust and consistent geodetic framework for the entire continent.

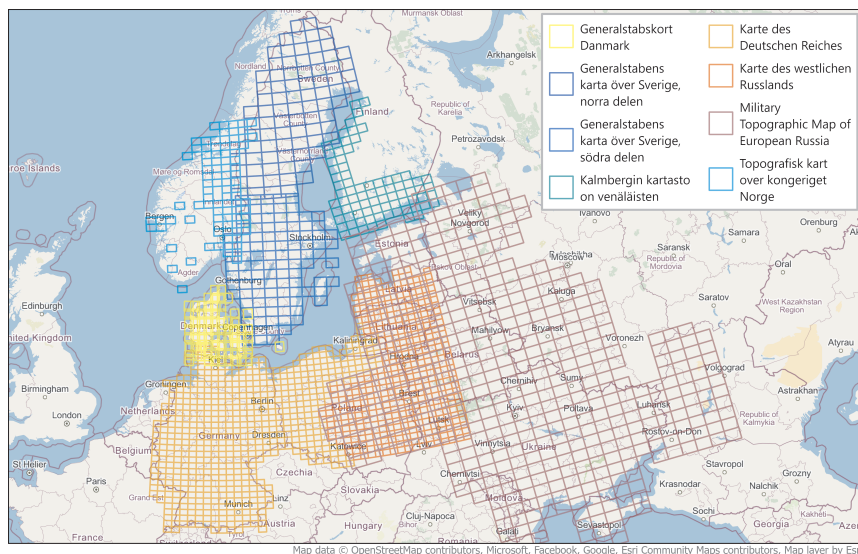


Figure 1: Mosaicked representation of the map sheet indices for different national map series in the Baltic Sea region around the year 1900. While the land area is comprehensively covered, clear differences exist in the underlying projection parameters. (Note: Around 1900, Norway and Russia did not have comprehensive map coverage at a scale of 1:100,000. An (incomplete) map index was compiled from available sheets.)

Table 1: Overview of national map series in the Baltic Sea region around the year 1900 with information on scales, used central meridians and reference systems (based on Alexander Supan 1887³⁵).

Title	Scale	Period	Central Meridian	Reference System
<i>Generalstabens karta över Sverige, norra delen</i> (Finland, Sweden, Norway)	1:200,000	1880–1940	Stockholm	Spén's on Clarke 1880
<i>Generalstabens karta över Sverige, södra delen</i> (Denmark, Norway, Sweden)	1:100,000	1880–1940	Stockholm ³⁶	Lambert conformal conic on Svanbergs's ellipsoid
<i>Generalstabskort Danmark</i> (Denmark, Germany)	1:100,000	1842–1899	Copenhagen	Prussian polyhedral projection, G5 projection on Clarke 1858
<i>Kalmbergin kartasto on venäläisten</i> (Finland, Russia)	1:100,000	1855–1856	(Pulkovo) ³⁷	Bonne projection on Bessel 1841
<i>Karte des Deutschen Reiches</i> (Austria, Belgium, Czechia, Denmark, France, Germany, Lithuania, Netherlands, Poland, Switzerland)	1:100,000	1878–1926	Ferro, partially Greenwich ³⁸	Polyhedral projection
<i>Karte des westlichen Russlands</i> (Estonia, Latvia, Lithuania, Poland, Russia)	1:100,000	1897–1917	Ferro ³⁹	Polyhedral projection
<i>Topografisk kart over kongeriget Norge</i> (Norway, Sweden)	1:100,000	1867–1956	Oslo (Kristiania)	Cassini-Soldner projection
<i>Военно-топографическая карта Европейской России</i> (Military Topographic Map of European Russia) (Belarus, Estonia, Latvia, Lithuania, Moldavia, Poland, Ukraine, Russia)	1:126,000	1846–1917	Pulkovo ⁴⁰ , Paris, Ferro, Warsaw	Bonne projection on Bessel 1841 ⁴¹

A milestone in early international cooperation was the establishment of the Baltic Geodetic Commission (BGK) in 1924. With the participation of Denmark, Germany, Estonia, Finland, Latvia, Lithuania, Poland, and Sweden, the

35 Supan, Alexander: Übersicht der offiziellen topographischen Landesaufnahmen. Geographischer Litteratur-Bericht Nr. 89–92, in: id. (ed.): Dr. A. Petermann's Mittheilungen aus Justus Perthes' Geographischer Anstalt. Band 33, Gotha 1887, p. 23.

36 Mugnier, Clifford J.: Grids & Datums—The Kingdom of Sweden, in: Photogrammetric Engineering & Remote Sensing 88 (2022), No. 5, pp. 289–291: p. 290, DOI: 10.14358/PERS.88.5.289.

37 Although the so called Kalmberg Atlas does not explicitly specify its prime meridian, its origin within the Russian military cartographic framework strongly suggests the use of the Pulkovo meridian as its longitudinal reference. This meridian was standard in Russian topographic works of the 19th century.

38 Reichsamt für Landesaufnahme: Das Reichsamt für Landesaufnahme und seine Kartenwerke, Berlin 1931, p. 68.

39 ibid.

40 Haag, Heinrich: Die Geschichte des Nullmeridians, Leipzig 1913, p. 72.

41 k.u.k. Reichskriegsministerium (ed.): Mitteilungen des k.u.k. Militärgeographischen Institutes. XXIV. Band, Wien 1905, p. 203.

BGK initiated an ambitious project: the creation of the so-called ›Baltic Ring‹. The aim was to establish a high-precision, closed chain of first-order triangulation points around the Baltic Sea. This almost 3000 km long polygon network was intended to connect the national networks and create a uniform geodetic base for the entire region.⁴² Although the project could not be completed due to the outbreak of World War II, it laid the foundation for later European networks.⁴³

Military and Technological Transformations

With the beginning of the 20th century, rapid technological innovation opened up new possibilities for land observation and surveying. Aerial photography soon became an important factor, especially for covering more remote areas.⁴⁴ The digitisation of land features from imagery and the use of photogrammetric techniques to derive terrain elevation had significantly simplified the creation and updating of topographic data.⁴⁵ Parallel to this, terrestrial surveying gradually improved due to the increasing accuracy of measuring instruments, yet the major advances towards more harmonised cartography in the 20th century were largely driven by international wars and military demands.

One notable example is the globally used Universal Transverse Mercator (UTM) coordinate system, which likely originated from German military developments around 1943/1944⁴⁶ and may have been independently invented or derived—possibly as a result of knowledge transfer—by the United States Army in the 1940s.⁴⁷ Nevertheless, it was the U.S. Army who adopted and globally established the UTM system in the 1950s. The system provides a global reference

42 Kakkuri, Juhani: The Baltic Geodetic Commission: Its Activities and Publications. Proceedings of the IAG General Assembly, Rio de Janeiro, published by Finnish Geodetic Institute, 1997.

43 Torge, Wolfgang: Geodesy. Third Edition, Berlin/New York 2001, pp. 188f.

44 Collier, Peter: The Impact on Topographic Mapping of Developments in Land and Air Survey: 1900–1939, in: Cartography and Geographic Information Science 29 (2002), No. 3, pp. 155–174, DOI: 10.1559/152304002782008440.

45 Smith, Scot E.: Topographic mapping, in: Sabine Grunwald (ed.): Environmental Soil-Landscape Modeling. Geographic Information Technologies and Pedometrics, Boca Raton/London/New York 2006, pp. 155–182.

46 Buchroithner, Manfred F./Pfahlbusch, René: Geodetic grids in authoritative maps—new findings about the origin of the UTM Grid, in: Cartography and Geographic Information Science 44 (2016), No. 3, pp. 186–200, DOI: 10.1080/15230406.2015.1128851.

47 War Department: Chapter 17—Military Grid Reference System, Section I. Military Grid System, 243. General, in: War Department Technical Manual. Orientation for Artillery, 30 June 1944, Washington 1944, p. 4 and p. 16.

within a conformal metric coordinate system, i.e., a coordinate system in which angles are correctly represented on the map, by using a systematic grid of local projections along central meridians within 6° wide zones. It builds on the work of Gauß⁴⁸ and Krüger⁴⁹ that was adopted by German cartography after 1917.⁵⁰ In the beginning, the UTM system used two ellipsoids in parallel: the 1866 Clarke ellipsoid⁵¹ for the contiguous United States and Alaska, and the Hayford (International) ellipsoid⁵² for the rest of the world. Only several decades later, with the introduction of the Geodetic Reference System 1980 (GRS80),⁵³ a global reference ellipsoid based on satellite geodesy was adopted at the *XVII General Assembly of the International Union of Geodesy and Geophysics* (IUGG) in Canberra, Australia, 1979.⁵⁴ This system has an accuracy that allows its use until present and is (quasi) identical with the World Geodetic System 1984 (WGS84)⁵⁵ which is the standard in satellite navigation.

The Cold War: A Divided Geodetic and Cartographic World

The era of pan-European geodetic cooperation ended abruptly with the division of Europe after 1945. The Baltic Sea became the seam between two hostile military blocs, leading to a complete decoupling of geodetic foundations and map series.

In the Western littoral states (Federal Republic of Germany, Denmark, Norway, with Sweden and Finland as a neutral buffer zone), geodetic unification was driven by NATO for military purposes. The result was the European Datum 1950 (ED50), based on the International Ellipsoid of 1924 (Hayford).⁵⁶ For cartographic representation, the Universal Transverse Mercator (UTM) coor-

48 Johann Carl Friedrich Gauß (1777*-1855†, isni.org/isni/00000000121257962).

49 Johann Heinrich Louis Krüger (1857*-1923†, isni.org/isni/00000000013497395).

50 Reichsamt für Landesaufnahme: Das Reichsamt für Landesaufnahme und seine Kartenwerke, p. 31.

51 Clarke, Alexander Ross: Geodesy, Clarendon Press Series, Oxford 1880, p. 319.

52 Hayford, John F.: The Figure of the Earth and Isostasy from Measurements in the United States. Special publication no. 82, Department of Commerce and Labor Coast and Geodetic Survey, Washington, Government Printing Office 1909, p. 174.

53 Moritz: Geodetic reference system 1980.

54 Melchior, P.: COMPTES RENDUS de la XVII Assemblée Générale de l'U.G.G.I. Canberra, 3–15 décembre 1979, publiés par le Secrétaire Général Paul Melchior, Deuxième partie, 1979, p. 621.

55 Department of Defense: World Geodetic System 1984. Its Definition and Relationship with Local Geodetic Systems, DMA Technical report, DMA TR 8350.2, Second Edition, 1991.

56 Hooijberg, Maarten: Geodetic Surveying and the European Datum, in: id.: Practical Geodesy: Using Computers, Berlin/Heidelberg 2007, pp. 91–105.

dinate system became the standard in the military sphere, enabling standardised, metric positioning across all NATO countries. However, civilian maps of the western Baltic Sea countries often remained stuck in their national systems for a long time, which continued to cause compatibility problems at the borders.⁵⁷ This period thus marked a phase of military standardisation, while civil map fragmentation still persisted.

For the Warsaw Pact region, the Soviet Union established its own strictly centralised and secret geodetic system for its sphere of influence. The German Democratic Republic, Poland, and the Baltic Soviet republics were forcibly integrated into this system. The geodetic basis was System 42 (S-42), internationally known as Pulkovo 1942. This datum referred to the Krassowski Ellipsoid of 1940, calculated in the USSR, which differed significantly in its dimensions from the Hayford ellipsoid. The Gauss–Krüger system was employed as the cartographic projection.⁵⁸ As in the Western Bloc, for civil purposes, each Member State of the Warsaw Pact used its own system.

Bridging Europe: The Post-1990 Geodetic Unification

The fall of the Iron Curtain revealed the full extent of the geodetic division. Creating a unified geodetic basis became a priority to support the political and economic integration of Europe. The driving force behind this unification was the IAG (International Association of Geodesy) sub-commission *EUREF* (European Reference Frame). The goal was to define and realise a unified, high-precision European reference system compatible with global systems like the WGS84 used by GPS. The result was the *European Terrestrial Reference System 1989* (ETRS89).⁵⁹ ETRS89 is based on the global GRS80 ellipsoid and fixed to the stable part of the Eurasian tectonic plate. It is the standard coordinate reference system across EU countries and typically used with UTM projection.⁶⁰ This continental scale initiative was supported by the technological advancements of

57 Iliffe, Jonathan C./Lott, Roger: *Datums and Map Projections: For Remote Sensing, GIS and Surveying*, Dunbeath, UK/Boca Raton, Florida 2008, p. 78.

58 Poder, Knud/Madsen, Frede: *The Connection of the East European countries to EUREF*, in: Gubler, E./Hornik, H. (eds.): *Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Ankara, 22–25 May 1996*, EUREF Publication No. 5, 1996, pp. 134–141.

59 Gurtner, W. et al.: *EUREF: The new European Terrestrial Reference Frame*. Proceedings of the 2nd International Symposium on Precise Positioning with the Global Positioning System (GPS '90), Ottawa, Canada 1990.

60 COMMISSION REGULATION (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoper-

the satellite era. Global Navigation Satellite System (GNSS), e.g., GPS, GLONASS, BEIDOU, Galileo, allow for highly precise location measurements on the Earth's surface from space. Nowadays, differential measurements combining the satellite-based estimates with correctional signals from fixed receiving stations allow accuracy in the sub-centimetre range even for mobile surveys.⁶¹

A crucial step in integrating the former Eastern Bloc countries was the EUREF-BAL '92 GPS campaign. Led by the Nordic Geodetic Commission (NKG), GPS measurements were carried out at points in the Baltic states, Poland, Germany, and Scandinavia. This campaign built the first precise geodetic bridge across the former system boundary and enabled the transformation of the eastern national networks into ETRS89.⁶² Cooperation was also institutionalised in hydrography through the Baltic Sea Hydrographic Commission (BSHC), which established the Baltic Sea Chart Datum 2000 (BSCD2000) to ensure consistent depth information throughout the Baltic Sea.⁶³ Another continent-wide decision was the adoption of the EU directive establishing the *Infrastructure for Spatial Information in the European Community* (INSPIRE⁶⁴). Its goal is to create a unified geospatial data infrastructure to support environmental policy and related activities. As part of INSPIRE, several geospatial reference data sets are to be produced in a harmonised way across Europe and made freely accessible.

Examples of Fragmentation in Topographic Maps

Several of the milestones on the path from fragmentation to harmonisation in cartography took decades to be implemented. This latency is mostly explained by the low frequencies of comprehensive updating of land surveys before the availability of satellite data. Especially in the 19th century and along the Prussian

ability of spatial data sets and services. Annex I, Section 2.2.1, ANNEX II, Section 1.2, 2010, ELI: data.europa.eu/eli/reg/2010/1089/oj.

61 Petropoulos, George P./Srivastava, Parshant K. (eds.): *GPS and GNSS Technology in Geosciences*, Amsterdam/Oxford/Cambridge, MA 2021, pp. 41–49.

62 Jaworski, L./Kryniski, J./Zielinski, J. B.: EUREF-BAL '92 GPS Observation Campaign, in: Gubler, E./Hornik, H. (eds.): *Report on the Symposium of the IAG Subcommittee for Europe (EUREF) held in Budapest, 17–19 May 1993*, EUREF Publication No. 3, 1993.

63 Schwabe, J. et al.: *The Baltic Sea Chart Datum 2000 (BSCD2000). Implementation of a common reference level in the Baltic Sea*, in: *International Hydrographic Review*, May 2020, pp. 63–83.

64 Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), 2007, ELI: eur-lex.europa.eu/eli/dir/2007/2/oj.

map series (*Preußische Meßtischblätter*) from the near-Baltic German regions, the slow introduction of new standards and the partly parallel maintenance of systems can be highlighted.

Figure 2 shows a digitised version of the sheet *Hadersleben* of the *Karte des Deutschen Reiches* (Map of the German Empire). The survey was performed in 1877 and the map series released in 1880. The presented edition dates to 1918, when the decision on the Greenwich Prime Meridian⁶⁵ was 34 years old. The coordinate system is still referenced to Ferro; however, the map frame includes the following remark: »Im Gradnetz der Landesaufnahme liegt Greenwich 17°39'57.6" east of Ferro.« (In the graticule of the topographic survey Greenwich lies 17°39'57.6" east of Ferro.)

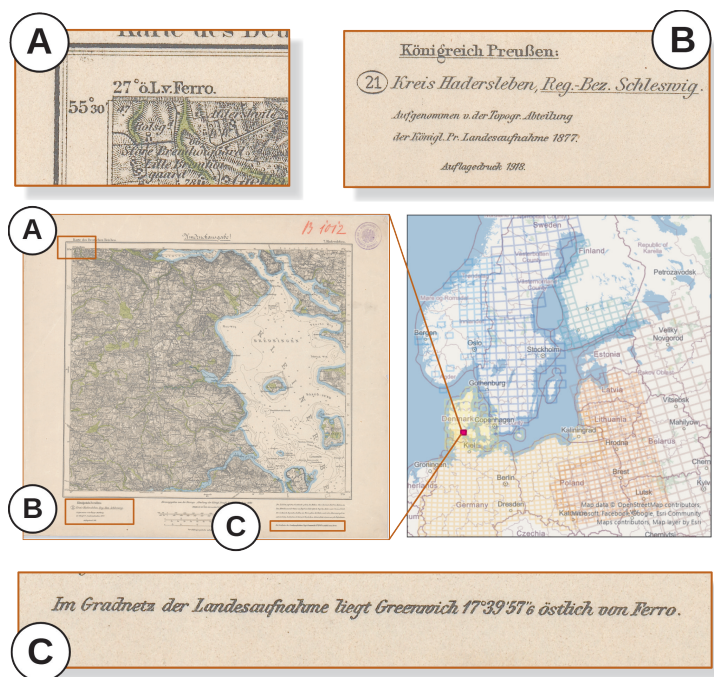


Figure 2: *Karte des Deutschen Reiches*, sheet 7. Hadersleben, edition from 1918 (B), Ferro as prime meridian was still in use (A). However, a note indicates the position of Greenwich relative to Ferro (C).

Later, both coordinate systems were shown (Figure 3), as displayed in an example from the *Meßtischblatt*, sheet *Greifswald*, survey 1885, corrected in 1920.

⁶⁵ The implementation of the resolutions of the 1884 Meridian Conference was significantly delayed in national practice due to political fragmentation.

The different ways of representing the transition between the systems in sheets from the same map series shows the challenges for cartography to adapt to new standards and to move from fragmented approaches to more harmonised ones.

Similarly, the symbology within maps also developed further and every new advancement led to transition periods. This can best be shown by looking at the techniques used to represent terrain elevation. For several decades, Prussian maps—like those of most other European countries—used hachures (German: *Schraffen*) to depict relative changes in elevation. Modern maps, by contrast, employ contour lines representing locations of equal elevation. In addition to the absolute information within the contour lines, their densities indicate steepness and the convergence or divergence of neighbouring lines represent the local morphology. The transition involved a significant amount of manual labour, meaning that there are some individual maps for which the transition had not been fully completed by the time the new edition was published. Figure 4 highlights such a sharp boundary between the traditional and new approach in a map published in 1888 and edited in 1918.

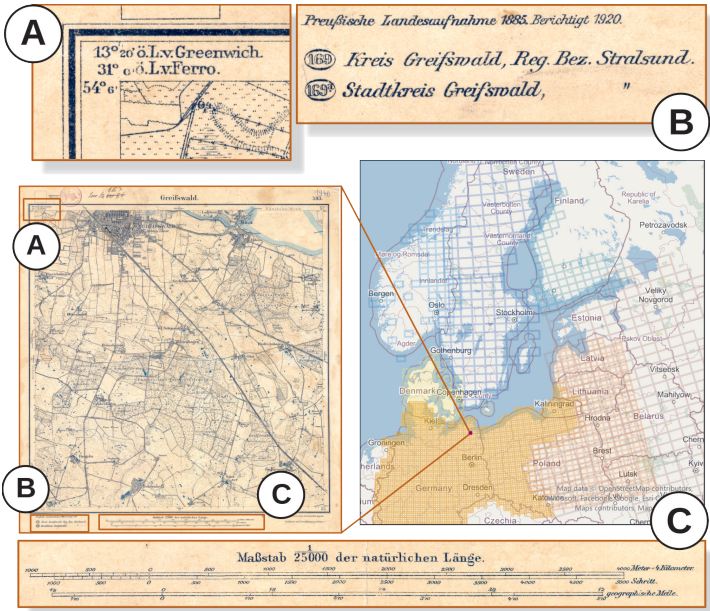


Figure 3: *Mefstischblatt*, sheet 593 (1460). Greifswald, edition from 1920 (B). The map frame shows both prime meridians: Ferro and Greenwich (A). The scale bar shows modern metres and antique length units, which are still in use (C).

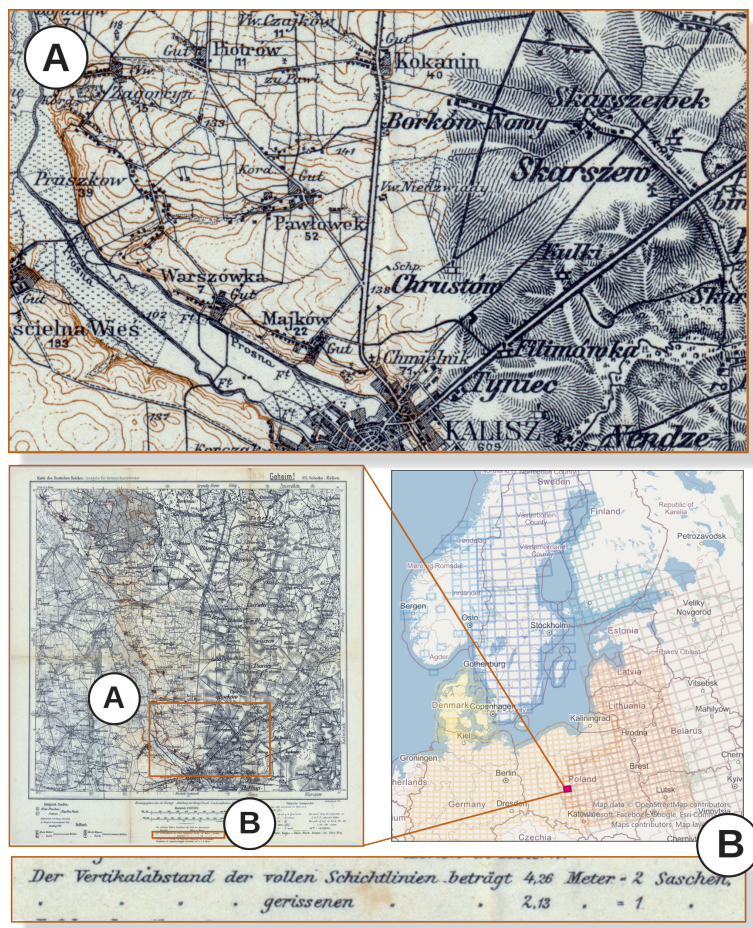


Figure 4: Karte des Deutschen Reiches, sheet 351. Sobotka–Kalisz. The map illustrates the transitional period between the use of outdated hachures and modern contour lines. In some cases, maps were only partially updated, resulting in the coexistence of hachures and contour lines. However, the contour lines still reference old vertical datums, such as the »Saschen« (1 Saschen = 2.13 metres).

Nevertheless, the fact that cartography placed a certain degree of importance on consistency in its products makes the results from different editions more comparable after updates to land survey. This can be seen in Figure 5 highlighting the city of Greifswald and its surroundings in the *Preußisches Meßtischblatt*⁶⁶ (scale 1 : 25,000) as released 1886 and 1940. The high efforts put into early editions

⁶⁶ Torge: Der lange Weg der preußischen Landesvermessung, p. 361.

allowed the authorities to maintain symbology throughout several decades. Therefore, the different editions appear uniform and the actual changes in topography, which were updated in 1920, can be clearly differentiated, e.g., additional buildings in the city's extension to the south-east.

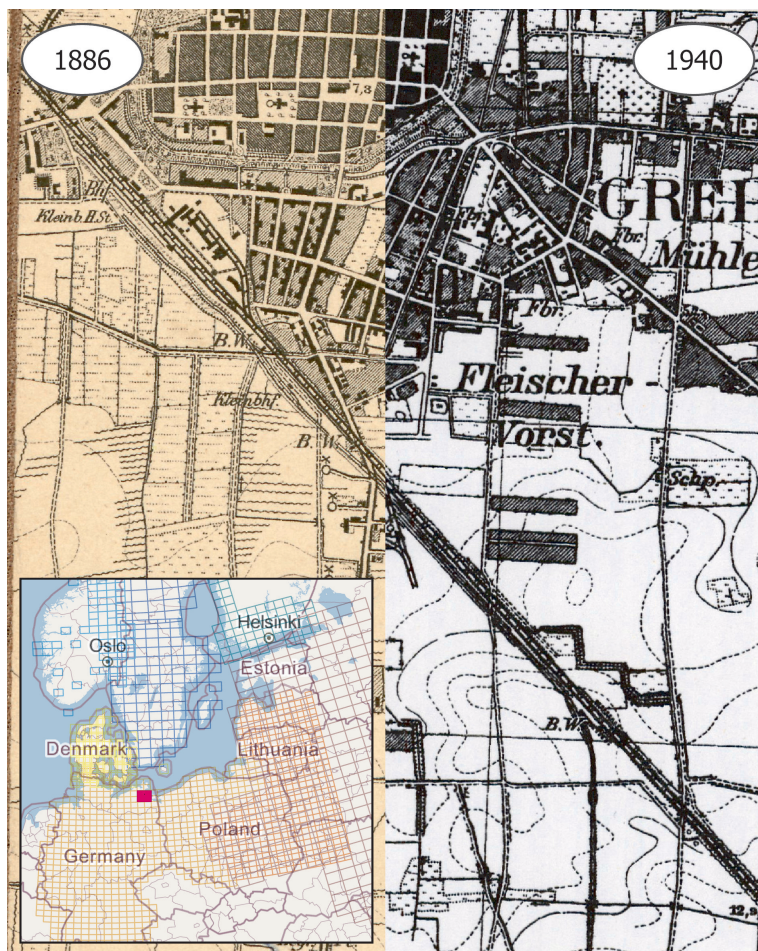


Figure 5: *Preußisches Meßtischblatt*, sheet 1946. Greifswald, edition 1886 (left) and 1940 (right). The development of the city is clearly visible by comparison—assisted by the consistency of symbolisation.

In summary, the examples illustrate the fragmentation of cartographic standards in the 19th century, when numerous national map series were launched in the countries bordering the Baltic Sea. Alongside technical advancements, the

necessity for standardisation of key cartographic conventions was progressively acknowledged and systematically addressed. Nevertheless, the required decisions unfolded over a long period, and even after the introduction of new regulations, it took several decades before they were fully implemented in map production.

Topographic Mapping and Transnational Data Provision in the 21st Century

Surveying and the creation of topographic maps in the 21st century are characterised by a high level of global standardisation. The SI System, global ellipsoids and internationally coordinated and harmonised satellite measurements mark the basis for information transfer across national boundaries. Although the coordinate reference systems may still differ, especially between countries on different continents, the digital age and GRS80/WGS84 as underlying, fully defined ellipsoids allow for an on-the-fly translation between standards. Web-based and interactive maps have become a major source for sharing spatial information. Via so-called *geoportals*, administrative topographic information is shared, to an increasing extent free-of-charge.⁶⁷ Parallel to this, community-based, free and open-source products, such as Open Street Map (OSM),⁶⁸ are becoming increasingly important in many areas of application, for example in maps for humanitarian missions.⁶⁹ They are organised transnationally and are often the most up-to-date,⁷⁰ and therefore replace official topographic maps in many respects. Moreover, topographic information is complemented by frequently updated information on land cover or land use derived from Earth observation satellite imagery, for example within the European Union's Copernicus Land Monitoring Service programme.

Geoportals are also increasingly being used to share scientific results or data products that may be used for scientific analyses. One example of such

67 European Commission: European legislation on open data, digital-strategy.ec.europa.eu/en/policies/legislation-open-data (09.03.2026).

68 OpenStreetMap, www.openstreetmap.org.

69 McGowan, Bethany Sherise: OpenStreetMap mapathons support critical data and visual literacy instruction, in: *Journal of the Medical Library Association* 108 (2020), No. 4, p. 649f., DOI: 10.5195/jmla.2020.1070.

70 Neis, Pascal/Zielstra, Dennis: Recent Developments and Future Trends in Volunteered Geographic Information Research: The Case of OpenStreetMap, in: *Future Internet* 6 (2014), No. 1, pp. 76–106, DOI: 10.3390/fi6010076; Borkowska, Sylwia/Bielecka, Elżbieta/Pokonieczny, Krzysztof: Comparison of Land Cover Categorical Data Stored in OSM and Authoritative Topographic Data, in: *Applied Sciences* 13 (2023), No. 13, 7525, DOI: 10.3390/app13137525.

geoportals is the IFZO Baltic Sea Region Geoportal.⁷¹ It gives users access to georeferenced compilations of digitised historic maps for selected time frames (e.g., Figure 1) or to results from multi-year mappings based on Earth observation data, like the *Baltic Sea Region Land Cover Plus* products.⁷² This way, regular updates on e.g., forest dieback or regrowth, peatland restoration or urban expansion are provided for the Baltic Sea region from region-wide harmonised data and models. Although such products do not achieve the geometric accuracy needed for official topographic maps, their regular updating and e.g., annual coverage of transnational regions, substitute information that was traditionally taken from topographic maps.

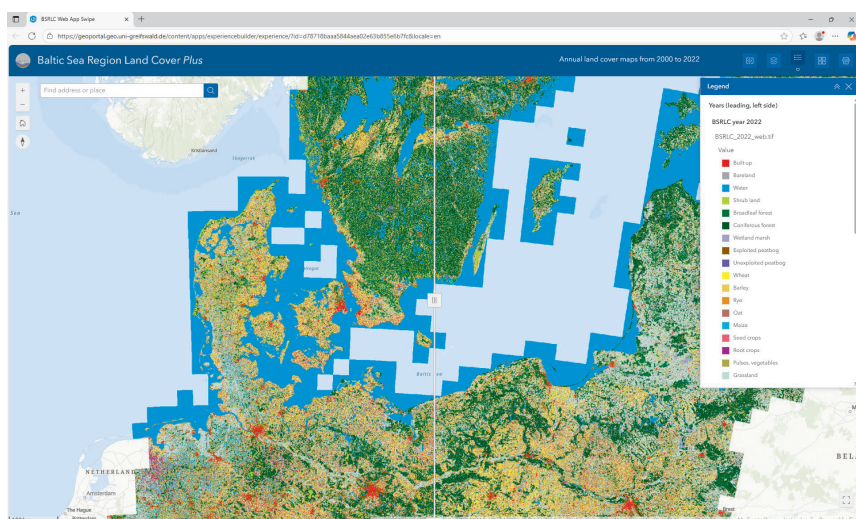


Figure 6: The BSRLC+ is presented as an interactive web map within the IFZO Geoportal. The application includes standard tools such as a map legend, distance measurement, location search, and a swipe tool for comparing land cover between two different years.

After more than three centuries of topographic map creation, a long way has been travelled towards complete international harmonisation in the field of topographic cartography. The state of technical development, international standards and digital data management capabilities no longer pose challenges

71 Interdisciplinary Centre for Baltic Sea Region Research (IFZO): IFZO Geoportal, ifzo-gis.g eo.uni-greifswald.de.

72 Pham, V.-D. et al.: BSRLC+: An annual land cover dataset for the Baltic Sea Region with crop types and peat bogs at 30 m from 2000 to 2022 (1.0) [Data set], Zenodo, 2024, DOI: 10.5281/zenodo.10653871.

for transnational map products. Nevertheless, administrative topographic information remains under national authority (and, in the case of Germany, even under state-level authority). This last step towards harmonisation at EU-level, and thus for most of the Baltic Sea region, requires only the will and consent of the member states. At the same time, thematic maps are already provided at the EU-level for an increasing number of fields and with steadily higher levels of detail, temporal frequency and mapping accuracy. Against the background of this process and the parallel development of community-based products, it seems only a matter of time before national topographic maps will be replaced by EU-wide (or even more expansive) initiatives for providing topographic information.

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