INTERNATIONAL SCIENTIFIC JOURNAL

Micro Macro & Mezzo
Geo Information

DOI: 10.5281/zenodo.17957669
ISSN: 1857-9000, EISSN: 1857-9019
UDC: 528:004

Book of Abstracts

International Scientific Conference

"Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges"

https://www.scrsproject.mk

October 31, 2025

North Macedonia

Editors-in-chief:

Bashkim Idrizi, Lyubka Pashova

Geo-SEE Institute

12/17/2025

BOOK OF ABSTRACTS

International Scientific Conference *"Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges" 2025*

DOI: 10.5281/zenodo.17957669

ISSN: 1857-9000 (printed version)
EISSN: 1857-9019 (electronic version)

UDC: 528:004

Publisher:
South-East European Research Institute on Geo Sciences (Geo-SEE Institute), Skopje, North Macedonia
www.geo-see.org

http://mmm-gi.geo-see.org

Free & Open Access

Preface

The present Book of Abstracts reflects the scientific and professional contributions presented at the International Scientific Conference **“Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges,”** held on **31 October 2025** at Mother Teresa University in Skopje within the framework of the national project *State Plane Coordinate Reference System of the Republic of North Macedonia (SCRS)*. Organized by the **Geo-SEE Institute**, and supported by leading geospatial organizations from Europe and the region, the event brought together experts from academia, public institutions, industry, and surveying organizations in order to share methodological experiences, present best practices, and discuss the practical implementation of a new national Coordinate Reference System (CRS) for North Macedonia in accordance with modern technological and European standards.

In the last decades, Geographic Information System (GIS) technology has become a fundamental pillar for data-driven decision-making, spanning land administration, engineering design, environmental monitoring, navigation, cadastre, large-scale mapping, territory planning, and other GIS-based workflows. As with most European states, the development of a modern CRS represents more than a technical upgrade—it provides the spatial framework on which national geospatial interoperability, data integration, and institutional efficiency are built. The conference therefore addressed the scientific, legal, technical, and institutional requirements for transitioning from historical mapping systems to a unified national CRS that aligns with ETRS89/GRS80, modern Global Navigation Satellite System (GNSS) positioning, the standards established by the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO), and European practices in data harmonization.

The contributions presented in this book demonstrate the depth and diversity of scientific expertise within the international geospatial community. Presentations from **Albania, Bulgaria, Croatia, Germany, Greece, Kosovo, North Macedonia**, **the Netherlands, Turkey,** and other countries provided comparative insights into national experiences—each illustrating different pathways and stages of modernization. Together, they formed a valuable body of knowledge for all countries that are redefining their CRS in the context of new technologies, legacy mapping systems, cross-border consistency, and performance requirements for modern surveying and high-resolution spatial data capture.

A central theme running through the contributions is the importance of balancing scientific rigor with practical implementation. On one side stands the mathematical and geodetic evaluation of map projections, deformation analysis, and datum transformation. On the other hand, the institutional reality is that a CRS must be accepted and used by practitioners at the national scale—surveyors, engineers, municipal GIS units, state mapping agencies, cadastre institutions, and environmental authorities. Several contributions demonstrated that adopting a new CRS is not only a scholarly or engineering task but also an institutional journey that requires legislation, standardization, registration in the European Petroleum Survey Group (EPSG) Geodetic Parameter Dataset, training, stakeholder consultation, dialogue, and well-planned migration strategies to prevent loss of data integrity.

The abstracts in this volume cover a broad spectrum of topics, reflecting the full lifecycle of national CRS development. Some contributions examine the historical evolution of national mapping systems—showing how long-standing coordinate systems were developed, used, and eventually constrained by technological advances. Others analyze modern transformation approaches, EPSG registration procedures, projection parameter optimization, error and deformation modeling, and practical methods to improve interoperability between legacy systems and GNSS-based reference frames. Many contributions highlight real case studies—such as the use of Light Detection and Ranging (LiDAR) and Unmanned Aerial Vehicle (UAV) surveys in Croatia and Bosnia and Herzegovina, high-precision mapping examples, and real-world institutional transformations—illustrating the transition from conceptual frameworks to measurable practical impact.

Several papers also point out that the national geodetic networks, which materialize reference systems, are no longer isolated national infrastructures. In an era of seamless digital mapping and cross-border spatial datasets, CRS modernization authorities must ensure compatibility with European spatial infrastructures, environmental information systems, and transnational data exchange. This is particularly relevant for Western Balkan states working toward harmonization with European reference frameworks, data reporting requirements, and digital standards. The growing global ecosystem of open data, open software, and shared transformation registries—such as those maintained by EPSG and PROJ.org—was recognized as a key enabler for transparency and interoperability in official geospatial systems.

This Book of Abstracts represents more than a collection of individual studies—it is a consolidated reflection of current developments in geodesy and national mapping within Europe. It shows how scientific theory, institution-building, legal updates, and practical engineering solutions converge to make modern coordinate systems meaningful and valuable. For North Macedonia, the conference marked a pivotal step from research to practical transition—from analysis and benchmarking of international experience toward the implementation of a modern state-plane coordinate reference system capable of supporting national spatial data infrastructure, large-scale mapping, cadastre, engineering, and sustainable geospatial development.

The editors would like to express their sincere appreciation to all authors, reviewers, organizations, sponsors, and participants who contributed to the success of the conference and to the scientific rigor of the presented materials published in this collection. Their dedication, shared expertise, and collaborative spirit made this issue possible and provided a solid foundation for advancing modern geodetic and cartographic practices in the region and beyond.

We hope that this book serves as a valuable reference for researchers, practitioners, institutions, and future projects that continue to build upon the shared mission of improving national geospatial systems, enhancing data interoperability, and advancing the geodetic science and practice of coordinate reference systems.

Editors in chief
Bashkim Idrizi
Lyubka Pashova
December 2025

Contents

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17956910

Standard Parallels Choice for the Lambert Conformal Conic Projection of Bulgaria – BGS2005

Temenoujka Bandrova [a,*], Todor Gyurov [a]

[a] *Department of Photogrammetry and Cartography, University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria, tbandrova@abv.bg, todor_g_22@abv.bg*

* Temenoujka Bandrova, *tbandrova@abv.bg*

Keywords: Lambert Conformal Conic projection, standard parallels, map distortions, BGS2000, BGS2005, Bulgarian coordinate system

Abstract:

This research examines the optimal selection of standard parallels and projection origin in the Lambert Conformal Conic (LCC) (Lambert, 1772) projection used for Bulgaria, focusing on the Bulgarian Geodetic Systems BGS2000 and BGS2005. By comparing different parameter sets, the study evaluates deformation distribution across Bulgaria's territory to determine the configuration with minimal and most uniform scale distortions. The findings indicate that parameters determined according to the cartographic "one-sixth rule" yield the most evenly distributed distortions, while the current BGS2005 configuration produces the highest distortions.

Accurate cartographic representation requires minimizing scale, angular, and areal distortions within projection limits. The Lambert Conformal Conic projection, widely applied to mid-latitude countries with east–west extensions, is suitable for Bulgaria's geographic form (41°14′–44°13′N, 22°21′–28°37′E). Bulgaria has historically employed LCC projections in several coordinate systems, evolving from the 1970 system to BGS2000 and the current BGS2005. Despite extensive research on geodetic and projection systems in Bulgaria, the linear and areal distortions of BGS2005's cadastral LCC projection have not been systematically analyzed. This study fills that gap, providing a comparative assessment and proposing improved parameters for future cadastral and mapping applications.

The research analyzes scale distortions (m) in five different LCC configurations:

1. BGS2000,
2. BGS2005 (Cadastral),
3. Airy's criterion,
4. One-fifth rule, and
5. One-sixth rule (Hinks, 1912).

Each projection is assessed through numerical modeling of the scale factor and its variation across Bulgaria's latitude range. Calculations are based on standard LCC formulas for cone constant, auxiliary functions, and polar radii (Pearson, 1990). Deformations are evaluated at 10′ latitude increments between Bulgaria's southernmost (41°14′N) and northernmost (44°12′N) points, and graphically visualized through deformation curves and thematic maps. Comparative parameters for all projections are summarized in comprehensive tables.

The results demonstrate that:

- BGS2005 achieves good accuracy between its standard parallels but shows increased distortions toward northern and southern extremes;
- BGS2000 provides better balance overall but still introduces higher errors at the extremes;
- The one-sixth rule delivers the most uniform distortions distribution across Bulgaria, minimizing differences between northern, central, and southern latitudes;

- Airy's criterion and the one-fifth rule yield intermediate results, with slightly higher distortions than the one-sixth rule.

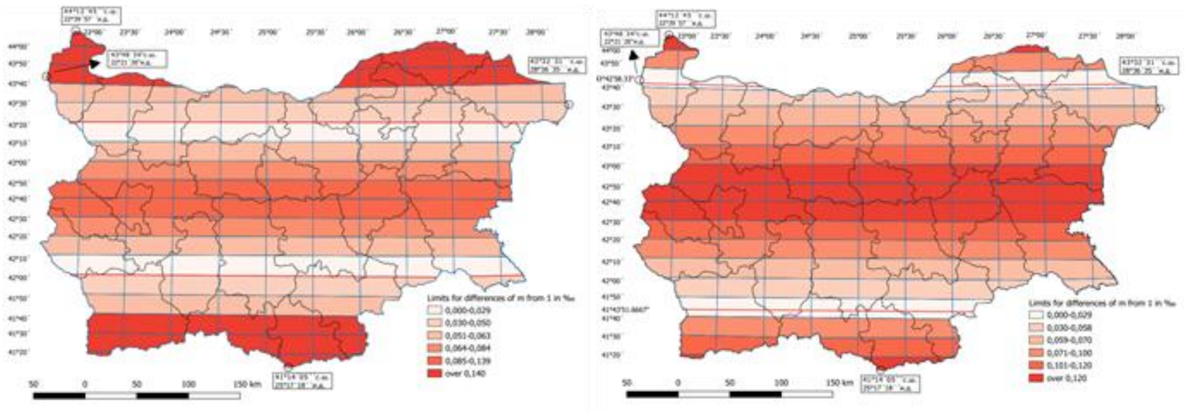
Quantitatively, the one-sixth rule achieves a total distortion variation of only 0.521‰, compared to 0.605‰ in BGS2005. Areal distortions patterns confirm the same trend (see Figure 1).

The study verifies that Bulgaria's geometric form and latitude span are best served by a two-standard-parallel LCC projection. However, the existing parameters in BGS2005 do not provide optimal distortion distribution for cadastral mapping. The proposed parameters based on the one-sixth rule (see Table 1) reduce overall scale variation, ensuring minimal distortion across the entire country, including border regions. This approach enhances positional accuracy and consistency for geospatial and cadastral data integration.

Table 1 Parameters according to the rule of one sixth for the Bulgarian territory

Projection	**Lambert conformal conical with two standard parallels**	
Standard parallels of the projection	ϕ_1	41° 49′ 48.9999″
	ϕ_2	43° 37′ 00.9999″
Central meridian	λ_0	25° 30' 00"
Origin of latitude	ϕ_0	42° 32′ 03.59″

The Lambert Conformal Conic projection remains the most suitable projection for Bulgaria due to its conformality and balanced distortion characteristics. Among the analyzed configurations, the one-sixth rule provides the most uniform deformation distribution and should be considered as a refinement for the Bulgarian Cadastral Coordinate System. The results contribute to improving the accuracy of geospatial datasets and the reliability of cadastral and engineering applications in Bulgaria.



(a) (b)

Figure.1 Distribution of the linear deformations, for the territory of Bulgaria according to BGS2005 (a) and according to the rule of 1/6 (b) The legend shows the limits of the differences of the linear scale along the parallel of 1 in per mil.

References

Lambert, J. H. (1772). Beyträge zum Gebrauche der Mathematik und deren Anwendung, Dritter Theil, VI. Chapter: Anmerkungen und Zusätze zur Entwerfung der Land- und Himmelscharten. Berlin. Reprint in German, 1894, Ostwald's Klassiker der Exakten Wissenschaften, no. 54: Leipzig, Wilhelm Engelmann, edited by Albert Wangerin. Translated into English and wrote the introduction W. R. Tobler: Notes and Comments on the Composition of Terrestrial and Celestial Maps, Ann Arbor, Univ. Michigan, 1972, Mich. Geographical Publication no. 8, 125 p. Second edition Esri Press, Redlands, 2011

Pearson II, F. (1990). Map Projections: Theory and Applications. CRC Press, INC., BocaRaton, Florida.

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957092

State Map Projection in Croatia

Miljenko Lapaine [a]

[a] *University of Zagreb, Faculty of Geodesy, mlapaine@geof.hr*

* Miljenko Lapaine, *mlapaine@geof.hr*

Keywords: map projection, HTRS96/TM, Croatia

Abstract:

One of the basic issues of official cartography is the choice of a national projection, or rather the choice of a national coordinate system. Such a choice was relevant at the beginning of the 20th Century, then with the creation of the Independent State of Croatia, and it was also relevant at the turn of the 20th and 21st centuries. In other words, after political-territorial changes, the issue of introducing a new map projection is usually discussed.

We inherited several coordinate systems from the Austro-Hungarian Monarchy. Every geodetic expert knows the worries and difficulties caused by numerous detailed points, or cadastral plans in different coordinate systems, and their connection into a whole.

The Gauß-Krüger projection has a very wide application in geodetic practice. In many European countries, this projection was accepted as the official state projection. It is known that it was chosen back in 1924 for the territory of the former Yugoslavia and that, until recently, the rectangular coordinates of the points of state triangulation were calculated and displayed in this projection.

Nikolaj Pavlovič Abakumov wrote about the issue of choosing the most appropriate projection for the Independent State of Croatia in 1942 and considered two variants of the Gauß-Krüger projection, their advantages and disadvantages.

Given the new circumstances that arose in the 1990s, and especially with regard to the shape of the Republic of Croatia and its extent, it was necessary to research and find the best possible map projection.

In early January 2000, a contract was signed between the State Geodetic Administration and the Faculty of Geodesy, University of Zagreb, on the development of the project *Geodetic and Cartographic Datums of the Republic of Croatia*. One of the three sub-projects was entitled *Proposal for Official Map Projections of the Republic of Croatia*, and the purpose of adopting this proposal was to:

- analyze existing map projections in the Republic of Croatia and the relationship of these projections to new technologies in geodesy,
- take into account the recommendations and experiences of international bodies and associations for the proposal of official map projections,
- maximally adapt the proposal of official map projections to national interests and needs for defining the geodetic spatial system of the Republic of Croatia,
- unambiguously define map projections with regard to existing map projections in Croatia, but also global world projection systems,
- propose the method and dynamics of introducing official map projections, and
- analyze the proposed method and dynamics of introduction in terms of the total costs of establishing official map projections in the Republic of Croatia.

The Government of the Republic of Croatia, at its session held on 4 August 2004, adopted a *Decision on the establishment of official geodetic datums and planar map projections of the Republic of Croatia*. This Decision states, among other things:

1. The coordinate system of the Transverse Mercator (Gauss-Krüger) projection – abbreviated HTRS96/TM, with the central meridian 16°30' and the linear scale on the central meridian 0.9999 is determined by the projection coordinate system of the Republic of Croatia for the area of cadastre and detailed state topographic cartography.
2. The coordinate system of the normal Lambert Conformal Conic projection – abbreviated HTRS96/LCC, with the standard parallels 43°05' and 45°55' is determined by the projection coordinate system of the Republic of Croatia for the area of overview state cartography.
3. The coordinate systems of map projections are based on the Croatian terrestrial reference system defined in point 1 of this Decision.
4. For the needs of the Armed Forces of the Republic of Croatia, the Universal Transverse Mercator (UTM) projection coordinate system is adopted in accordance with the Standardization Agreement "STANAG 2211", NATO member states, 5th edition of 15 July 1991.

Furthermore, the State Geodetic Administration was tasked with introducing new official geodetic datums and map projections into official use, no later than January 1, 2010.

The lecture will discuss the definition of the HTRS96/TM projection, as HTRS96/LCC has not yet found application. Reflections on the need to introduce new official map projections in Croatia began 30 years ago, and more than 20 years have passed since the official decision on new projections. Therefore, it is necessary to consider the consequences of changing the coordinate system in Croatia on maps and other forms of spatial data, on their quality, possibilities of use, and what advantages or problems it has brought.

The implementation of the HTRS96/TM system in the past 20 years since its official adoption, or 15 years since the official entry into force of the new geodetic reference system, has largely failed. Research has shown that the lengths, and especially the areas of parcels in the cadastre, are recorded and stored with distortions due to the projection.

Then it should not be surprising that the actual situation and that recorded in the cadastre, or land register, are incoherent. Neither satellites nor drones will solve the problems described. It is solely a matter of (lack of) knowledge.

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957195

Coordinate Systems and Map Projections Used in Mapping and GIS Activities in Turkey

İbrahim Öztuğ Bildirici [a]

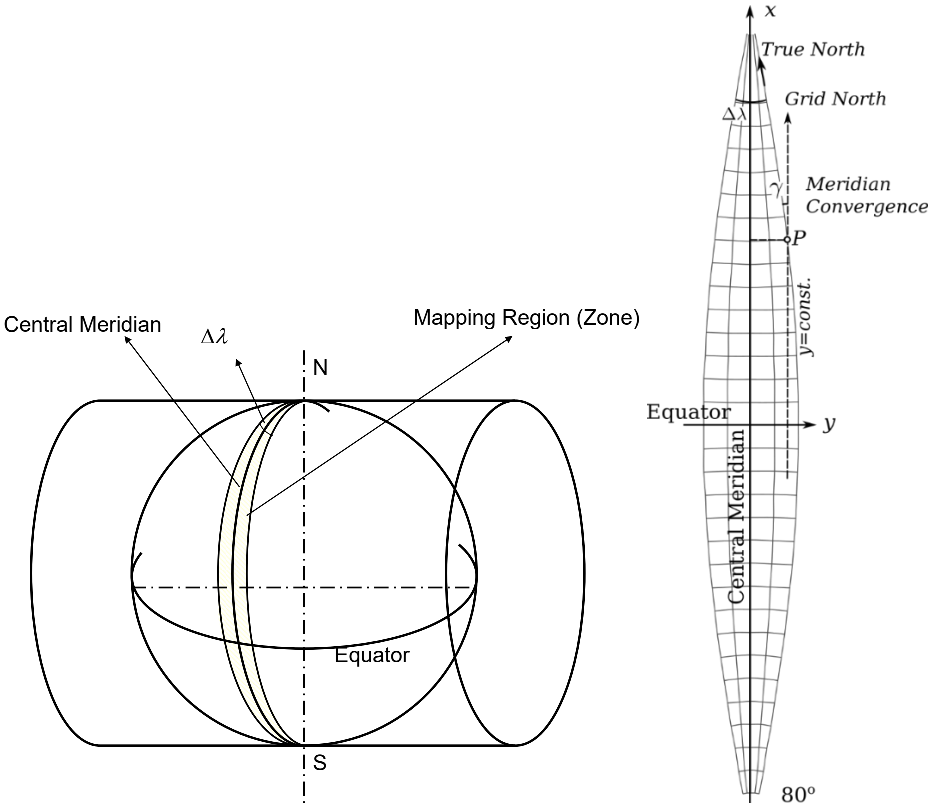
[a] *Konya Technical University, Faculty of Engineering & Natural Sciences, Department of Geomatics Engineering, Selçuklu, Konya, Türkiye. Iobildirici@ktun.edu.tr*

* İbrahim Öztuğ Bildirici, *iobildirici@ktun.edu.tr*

Keywords: Map Projections, Transverse Mercator Projection, UTM, EPSG 4326

Abstract:

Map projections and coordinate reference systems (CRS) play a crucial role in mapping and Geographical Information Systems (GIS) applications. In Turkey, large-scale mapping is standardized via a juridical regulation, the Large-scale Map and Geospatial Data Production Regulation of 2018 (BÖHHBÜY, 2018). According to the regulation, the reference frame is TUREF with the GRS80 Ellipsoid, and the map projection is Transverse Mercator (TM) implemented in 3-degree zones (Figure 1). The regulation applies to official map production at scales of 1:5000 and larger. In particular, local authorities (municipalities) and nationwide governmental institutions are required to comply with it in their mapping activities. In the past, large-scale mapping was carried out using the ED50 datum and the TM projection. As a result, there are still officially valid maps and geospatial datasets in that coordinate system. However, transforming between the ED50 and GRS80 datums is challenging, mainly because ellipsoidal heights in the ED50 datum are not available. To address this, transformation models based on predicted ED50 heights have been published, which can be used within certain accuracy limits. (Aktuğ et.al.,2011).



(a) (b)

Figure 1. a) The projection principle of TM Projection, b) The plane coordinate system of a zone

In transverse cylindrical projections, the differential scale, or scale factor, increases with distance from the central meridian. The maximum increase occurs at the edges of the zone. Additionally, topographic heights also affect the scale, with significant influence at higher altitudes, starting from about 1000 m. Since topographic heights are changing up to 5000 m in Turkey, the total scale factor may exceed the acceptable limits in large-scale mapping (Bildirici et.al, 2017; Bildirici, 2023; Idrizi, 2014). In this study, an analysis was conducted by using 11400 regularly spaced points within the territory of Turkey. For the height estimation, a regional Digital Elevation Model (DEM) downloaded from the General Bathymetic Chart of the Oceans (GEBCO; URL1) was used. Its resolution is 15 arc-seconds. The results are presented in Table 1, where the maximum scale factor resulting from the projection and topography is approximately 836 ppm. For large-scale topographic mapping, these values are assumed to be high (Iliffe 2017). To diminish the scale increase, a standard scale factor (m_0) can be used. Since the 3-degree zones can be assumed narrow enough, m_0 is taken as 1. To avoid negative values, false easting and false northing coordinates are used. In the Turkish TM system, a false easting value of 500,000 m is used.

Table 1. Scale factor (SF) analysis within the territory of Turkey (Using 11400 points)

	SF by Projection	**SF by Topography**	**Total SF**
Max.	1.000225 (225ppm)	1.000792 (792ppm)	1.000836 (836ppm)
Average	1.000068 (68ppm)	1.000146 (146ppm)	1.000214 (214ppm)

The country's territory is divided into 9 zones, each 3 degrees wide in longitude. Actually, 9 different coordinate systems are in use. This is an interrupted system and has disadvantages when working areas that span two zones. In such working areas, the scale factor caused by map projection reaches maximum values. Additionally, 3-degree zones are constructed in accordance with 6-degree UTM zones (Figure 2). So, one of every 2 zone shares the same central meridian with UTM. Since $m_0 = 0.9996$ in the UTM system, the TM and UTM zones sharing the same central meridian are not the same in terms of coordinates. This fact is sometimes confusing.

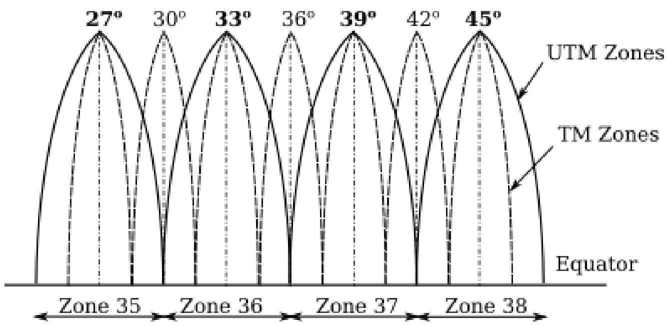


Figure 2. TM and UTM Zones

Medium-scale topographic mapping in Turkey is carried out by the Directorate General for Mapping, the National Mapping Agency, which is responsible for producing the 1:25,000, 1:50,000, 1:100,000, and 1:250,000 map series. For medium-scale mapping, the UTM system with the WGS84 datum has been in use since 2002; before that, the ED50 datum was employed. The UTM is an internationally defined coordinate reference system. The standard scale factor (m_0) is set at 0.9996, with a false easting of 500,000 m. For the southern parts of the zones, a false northing of 10,000,000 m is applied. As is well known, the UTM system encompasses 120 different coordinate systems, making it an interrupted projection system.

Both TM and UTM are interrupted systems and are not eligible for depicting the whole country. Therefore, the Lambert Conformal Conic (LCC) projection is mainly used in small-scale mapping. Current Turkey maps use LCC with standard parallels of $36°30'$ and $41°$. The central meridian is taken as $35°$. Since the maps produced are small-scale, and the projection does not cause a significant scale change, the standard scale factor is taken as 1.

Using geographic coordinates directly as a coordinate reference system is common in Turkey, as in many other countries. This is widely known as EPSG:4326. EPSG stands for the *European Petroleum Survey Group*, which developed a standard coding system for coordinate reference systems and map projections. In fact, EPSG:4326 corresponds to the equidistant cylindrical projection in the normal aspect. Although this projection is not suitable for mid- and high-latitude regions, it is sometimes used for mapping in Turkey. Such maps depict the country as compressed in the north–south direction, resulting in a misleading representation. Figure 3 illustrates the appearance of Turkey in EPSG:4326 compared with the Lambert Conformal Conic (LCC) projection.

For the mathematical background of the Transverse Mercator (TM) and Lambert Conformal Conic (LCC) projections, the following sources can be consulted: Bildirici (2023), Bugayevskiy & Snyder (1995), Snyder (1987), and Snyder (1993).

Figure 3. The appearance of Turkey in LCC and EPSG4326

References

Aktuğ, B., Seymen, S., Kurt, M., Parmaksız, E., Lenk, O., Sezer, S., Özdemir, S. (2011). Datum Transformation between ED-50 (European Datum-1950) and TUREF (Turkish National Reference Frame), Harita Dergisi, 146. https://www.harita.gov.tr/uploads/files/articles/ed-50-european-datum-1950-ile-turef-turkiye-ulusal-referans-cercevesi-arasinda-datum-don-1116.pdf

Bildirici, İ.Ö. (2023). Kartografya, 3rd Edition, Atlas Akademi Yayınevi, Konya.

Bildirici, İ.Ö., Berber, M., Kılıç, A. (2017). The Distribution of the Total Scale Factor in Large Scale Mapping in Turkey by Map Projection and Topography, International Symposium on GIS Applications in Geography & Geosciences, Çanakkale, Turkey.

BÖHHBÜY (2018). Büyük Ölçekli Harita ve Harita Bilgileri Üretim Yönetmeliği, Resmi Gazete, 26.06.2018, No: 30460.

Bugayevskiy, L. M., & Snyder, J. (1995). *Map projections: A reference manual*. CRC Press.

Idrizi, B. (2014). Length Differences between Topography Surface and Map Projections; Case Study: Country Area of Macedonia, 5th International Conference on Cartography and GIS. June 15-20, 2014, Riviera, Bulgaria ISSN: 1314-0604, Eds: Bandrova T., Konecny M.

Iliffe, J. C. (2017). The development and analysis of quasi-linear map projections. *Cartography and Geographic Information Science*, *45*(3), 270–283. https://doi.org/10.1080/15230406.2017.1325332

Snyder, J. P. (1987). *Map projections--A working manual* (Vol. 1395). US Government Printing Office.

Snyder, J. P. (1997). *Flattening the earth: two thousand years of map projections*. University of Chicago Press.

URL1: GEBCO Data Download, https://download.gebco.net/, accessed 20.09.2025.

Geo Information

Special issue – Book of Abstracts

DOI: 10.5281/zenodo.17957279

Some key facts for the realization of a modern National Geodetic Reference System/Frame: The Hellenic case

Dimitrios Ampatzidis [a*], Alexandros Konstantinidis [a], Konstantinos Papatheodorou [a]

[a] *Department of Surveying and Geomatics Engineering-International Hellenic University, dampatzi@ihu.gr, akonsta@ihu.gr conpap@ihu.gr*

* Dimitrios Ampatzidis, *dampatzi@ihu.gr*

Keywords: geodetic reference system, ITRF, ETRS89, geodetic datum

Abstract:

The realization of a modern National Geodetic Reference System/Frame (NGRSF) for each country plays a crucial role in many applications, such as cadastre, public works, and, lately, the monitoring of climate change (at least at the local scale).

The idea of a national geodetic reference system is quite old; the first attempts date back to the 18th century. The majority of national geodetic datums were oriented for the needs of each country separately, ignoring any regional or global sense of connection. The advent of the satellite era revolutionized the meaning of the geodetic reference system, allowing interconnection at the regional or/and global level. The establishment of the International Terrestrial Reference System (ITRS), which is materialized in its numerous realizations (International Terrestrial Reference Frames-ITRFs), provides a plethora of solutions for the realization of a geodetic reference system/frame in a pure modern sense. In addition, the European Terrestrial Reference System of 1989 (ETRS89) is a rigorous regional densification of ITRF, which is constrained to follow the motion of the Eurasian plate.

The main advantage of the modern NGRSF is the accurate 3D positioning. Furthermore, the NGRSF should provide solid and reliable information about the geodynamic processes, through the estimation of 3D velocities. However, there are some issues that should be considered and solved. The first one is the connection of a modern NGRSF with the old geodetic infrastructure. This may not be a simple task, since the fact that the old geodetic datums carry significant inconsistencies. In addition, a solid and rigorous mathematical procedure should be implemented, which allows the connection of the NGRSF ITRFs or/and a regional Terrestrial Reference Frame, in order to be consistent with the state of the art in accurate positioning.

In the present study, we will discuss the NGRSF situation in Greece, its challenges, and some thoughts for future research in this direction, taking into account the geophysical perplexity of the Hellenic Area.

References

Altamimi, Z., Rebischung, P., Collilieux, X. et al. (2023). ITRF2020: an augmented reference frame refining the modeling of nonlinear station motions. J Geod 97, 47. https://doi.org/10.1007/s00190-023-01738

Ampatzidis, D. (2011). Study for an optimal Geodetic Reference Frame realization in the Hellenic area. PhD Dissertation, Department of Geodesy and Surveying, Aristotle University of Thessaloniki (in Greek).

Ampatzidis, D. et al. (2025). The alignment of PPP-derived coordinates to a local geodetic reference system through a reliable velocity field: case study in Greece, Bulletin of Geophysics and Oceanography Vol. 66, n. 1, pp. 43-56.

Ampatzidis, D., Perperidou, D. G. C., Vartholomaios, A., Demirtzoglou, N., & Moschopoulos, G. (2025). The Local Area Distortion Factor (LADF): Resolving Property Area and Spatial Deviations from Geodetic Transformations in the Greek Cadastre. Land, 14(5), 1071. https://doi.org/10.3390/land14051071

Bitharis, S., Ampatzidis, D., Pikridas, C. (2017). An optimal geodetic dynamic reference frame realization for Greece: methodology and application. Ann Geophys 60(2):S0221. https://doi.org/10.4401/AG-7292

Boucher, C., Altamimi, Z. (1989). The initial IERS Terrestrial Reference Frame, IERS Technical Note No. 1. Paris: Central Bureau of IERS - Observatoire de Paris.

Chatzinikos, M. (2013). *Study of the earth's crust displacements in the area of Greece analyzing GNSS data* PhD Thesis, Dept. of Rural and Surveying Engineering, Aristotle University of Thessaloniki, Greece (in Greek).

Chatzinikos, M., & Kotsakis, C. (2016). Appraisal of the Hellenic Geodetic Reference System 1987 based on backward-transformed ITRF coordinates using a national velocity model. Survey Review, 49(356), 386–398. https://doi.org/10.1080/00396265.2016.1180797

Gubler, E., Poder, K., Hornik, H. (eds) (1992). Report on the Symposium of the IAG Subcommission for the European Reference Frame (EUREF). Florence 28-31 May 1990: Report.

Hellenic Mapping and Cadastral Organization (1987). The Hellenic Geodetic Reference System 1987 Report, Ministry of Environment, Urban Planning and Public Works (in Greek).

Katsambalos, K., Kotsakis, C. and Gianniou, M. (2010). Hellenic terrestrial reference system 2007 (HTRS07): a regional realization of ETRS89 over Greece in support of HEPOS. Bulletin of Geodesy and Geomatics, LXIX (2–3), pp. 151–64.

Special issue – Book of Abstracts

DOI: 10.5281/zenodo.17957345

Challenges and Harmonization of Local Datum Transformations within the Coordinate Reference Systems of North Macedonia

Zoran Cvetkovski [a,*], Nikola Ribaroski [b]

[a] *Cvetkovski Consulting, zorcv@hotmail.com*
[b] *Chamber of Trade Surveyors of Macedonia, nikola_ribarovski@yahoo.co.uk*

* Zoran Cvetkovski, *zorcv@hotmail.com*

Keywords: Geodetic datum, North Macedonia, Coordinate Reference System, Harmonization, Transformation

Abstract:

Accurate, reliable, and interoperable coordinate reference systems (CRS) form the basis of all modern geospatial, surveying, engineering, and cadastral activities. In North Macedonia, the transition from historical national mapping frameworks to modern European standards has necessitated the development of transformation solutions capable of linking legacy data with contemporary positioning techniques, particularly those derived from GNSS observations. This paper reviews the legal framework governing the spatial and horizontal reference systems of North Macedonia and critically examines the technical and operational challenges associated with datum transformation between the Bessel-based national system and the ETRS89 standard. Furthermore, practical considerations, implementation methods, and recommendations for reducing cumulative field and design errors are presented, alongside a strategy for national harmonization through the adoption of a unified transformation parameter set.

The geospatial environment of North Macedonia is shaped by a dual reality: a long-established national coordinate reference system based on the Bessel 1841 ellipsoid and the Gauss–Krüger projection, and a modern legislative requirement aligning the country with the European Terrestrial Reference System 1989 (ETRS89). While ETRS89 forms the official spatial reference system under national law, a significant amount of spatial and infrastructure information continues to exist in the historical system. The coexistence of these systems has created a need for accurate, stable, and operationally practical transformation models to allow for seamless data integration, long-term consistency, and minimal distortions in engineering and cadastral applications.

Article 40 of the national Spatial Reference System law defines ETRS89 as the official three-dimensional terrestrial coordinate reference system for the Republic of North Macedonia. The adoption of ETRS89 ensures compatibility with contemporary European geodetic standards, accurate GNSS positioning, and long-term stability aligned with Eurasian tectonic dynamics.

Article 41 defines the horizontal reference system traditionally used in mapping, based on the Bessel ellipsoid (1841) with an origin point located in Hermannskogel. Positions within this system are expressed in two-dimensional geodetic latitude and longitude and then projected onto a plane coordinate system via the national cartographic system.

Article 42 establishes the Gauss–Krüger projection as the official state map projection with a 3° meridian zone, a central meridian at 21° E, a central scale factor of 0.9999, and standardized false easting and northing parameters. These standards have long ensured national uniformity but also represent a legacy system that predates satellite-based geodesy.

The transition from the classic Bessel-based CRS to ETRS89 introduces several key operational challenges:

1. Non-uniform historical distortions: Older geodetic networks contain accumulated observational and adjustment errors that vary spatially. This prevents the use of a simple universal transformation without location-specific corrections.
2. Local accuracy requirements: Engineering, cadastral, and construction projects often demand accuracies at the 10–15 cm level or better. Standard global seven-parameter solutions may not consistently meet this requirement.
3. Inconsistency across zones and regions: Changing projection zones or mixing data sources can introduce boundary mismatches, cadastral parcel offsets, and discontinuities in project design and infrastructure alignment.

4. Risk of operational errors: Field surveyors routinely face the risk of selecting unsuitable transformation parameters, leading to inaccuracies in stakeout, alignment, and infrastructure positioning.

These issues highlight the need for transformation models that are both technically robust and straightforward enough to be consistently applied across different organizations and regions.

North Macedonia has adopted two primary transformation methodologies:

1 Point-by-Point (MAKTRAN)

This approach uses a database of known common points in both reference systems. In a new survey, the surrounding control points are used to compute transformation parameters using either the Bursa-Wolf or Molodensky-Badekas models. In this method, transformation parameters are generated locally based on the best available neighborhood fit. But this is a one-way direction. If you want to do a stakeout in some areas, you will find that you need to decide which parameters to use.

2 Grid-Based Transformation

Transformation parameters are computed in blocks, typically 10 km × 10 km, allowing local variations in the old network to be absorbed. Each block contains fitted transformation coefficients based on control points within its boundaries. While offering high accuracy, this method requires careful implementation and data management to avoid edge discontinuities. In other words, you must be careful which zone is selected.

GNSS observations can be processed directly in ETRS89 and transformed into the national system using single- or multi-parameter transformations. Classical observations (traverse or resection methods) remain essential for infill surveys, requiring high-quality transformation parameterization to maintain consistency with GNSS solutions.

Surveying practice across North Macedonia confirms several recurring issues:

- 10–15 cm positional discrepancies may appear even when correct transformation parameters are applied, reflecting the historical imperfections of the legacy network.
- Boundary inconsistencies, particularly in project designs and expropriation lines, emerge when different organizations apply different transformation strategies or work across block boundaries.
- Construction site alignment errors can accumulate when subcontractors or inspectors rely on different transformation datasets or inconsistent software workflows.

Based on experience from large-scale infrastructure projects and national-level surveys, the authors recommend the adoption of a unified transformation parameter system. Key advantages include:

- Improved data integrity across all surveyors and institutions.
- Elimination of unnecessary calculations, reducing opportunities for operator error.
- Long-term stability irrespective of future technological evolution.
- Consistent national referencing, enabling problem-free integration of past, present, and future datasets.

A unified national transformation parameter set represents a strategic move toward sustainable and interoperable spatial information infrastructure.

The modernization of North Macedonia's geodetic infrastructure represents a necessary evolution toward fully integrated European and global geospatial standards. As legacy datasets continue to serve engineering, cadastral, and infrastructural needs, a reliable and harmonized transformation framework is essential to preserve positional coherence and operational effectiveness. A unified transformation standard, supported by legislation and widely implemented across public and private sectors, will ensure the integrity, accuracy, and sustainability of the national spatial reference system for decades to come.

References

Idrizi, B. (2021). Redefining of "EPSG" and "PROJ" for current State Coordinate Reference System of the Republic of North Macedonia. *Proceedings of the International Cartographic Association, 4,* 45. https://doi.org/10.5194/ica-proc-4-45-2021

Institute, G. (2025, October 10). National Scientific Project: State Plane Coordinate Reference System - Republic of North Macedonia. https://doi.org/10.17605/OSF.IO/MPUHG

Agency for Real Estate Cadastre. (2025, October). MAKPOS. https://makpos.katastar.gov.mk/SBC/Account/Index?returnUrl=%2FSBC

Agency for Real Estate Cadastre. (2025, October). MAKTRAN. https://maktran.katastar.gov.mk/wmaktrans/Login.aspx

Idrizi, B. (2023). Current conditions, opportunities and deficiencies of using State Coordinate Reference System of North Macedonia from international EPSG and PROJ databases. Abstracts of the International Cartographic Association, 6, 297. https://doi.org/10.5194/ica-abs-6-297-2023

Official Gazette No. 55. Year 2013. Law for real estate cadaster. Agency for real estate cadaster. Skopje. North Macedonia. https://www.katastar.gov.mk/wp-content/uploads/Regulativa/zakoni/zakoni/Zakon%20za%20KN%202013.pdf

Official Gazette No. 151. Year 2013. Regulation for basic geodetic works. Agency for real estate cadaster. Skopje. North Macedonia. https://www.katastar.gov.mk/wp-content/uploads/Regulativa/Pravilnici/osnovni%20geodetski%20raboti.pdf

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957416

UAV LiDAR and GNSS Surveys for High-Accuracy Spatial Data Acquisition Case Studies from Croatia and Bosnia and Herzegovina

Nikola Kranjčić [a,*], Vlado Cetl [a], Hrvoje Matijević [a], Danko Markovinović [a]

[a] *University North, Department of Geodesy and Geomatics, nkranjcic@unin.hr ; vcetl@unin.hr ; hmatijevic@unin.hr ; danko.markovinovic@unin.hr*

* Nikola Kranjcic, *nkranjcic@unin.hr*

Keywords: UAV LiDAR, GNSS RTK/PPK, Coordinate Reference System, CROPOS, FBiHPOS, DEM/DSM, Spatial Data Infrastructure

Abstract:

The acquisition of high-accuracy spatial data is essential for geodesy, civil engineering, cadastre, and environmental monitoring. This paper presents the integration of UAV-based LiDAR mapping and GNSS RTK/PPK positioning as a methodological framework for ensuring centimeter-level precision in national and regional spatial data infrastructures.

Surveys were performed in Croatia (Donja Višnjica, Gornje Jesenje, Jakopovec, Kapelščak, Laz Bistrički, Strmec) using the CROPOS GNSS network within the official HTRS96/TM coordinate system, and in Bosnia and Herzegovina (Jezerac well, Goranci – Mostar) using the FBiHPOS network within the official MGI 1901 / Balkans zone 6 system. These dual frameworks emphasize both the opportunities and challenges of cross-border geospatial interoperability (Idrizi et al., 2018).

A DJI Matrice 350 RTK UAV equipped with a DJI Zenmuse L2 LiDAR sensor and supported by an Emlid Reach RS2 GNSS receiver enabled surveys with centimeter-level accuracy (RMSE: X = 0.006 m; Y = 0.005 m; Z = 0.007 m). Data were processed in DJI Terra and Lidar360, producing dense point clouds (>240 pts/m²), high-resolution orthophotos (~2–3 cm GSD), and DEM/DSM products.

Results highlight that UAV-LiDAR surveys integrated with national GNSS infrastructures not only ensure compatibility with CROPOS and FBiHPOS, but also strengthen interoperability with European systems such as ETRS89 (Idrizi, 2021). This contributes to sustainable, harmonized spatial data infrastructures supporting scientific research, engineering applications, and long-term monitoring. Results are seen in Table 1, and a comparison of DEM and DSM generated from UAV-LiDAR surveys is seen in Figure 1.

Table 1. Summary of UAV-LiDAR Survey Parameters

Parameter	Dataset	Resolution/scale
UAV platform	DJI Matrice 350 RTK	DJI Matrice 350 RTK
LiDAR sensor	DJI Zenmuse L2	DJI Zenmuse L2
GNSS corrections	CROPOS (RTK/PPK)	FBiHPOS (RTK)
Coordinate system	HTRS96/TM (EPSG:3765)	MGI 1901 / Balkans zone 6 (Gauss-Krüger) (EPSG:3908 or EPSG:8678)
Point cloud density	~240 pts/m²	~247 pts/m²
Horizontal accuracy (RMSE)	0.007 m	0.006 m
Vertical accuracy (RMSE)	0.014 m	0.007 m

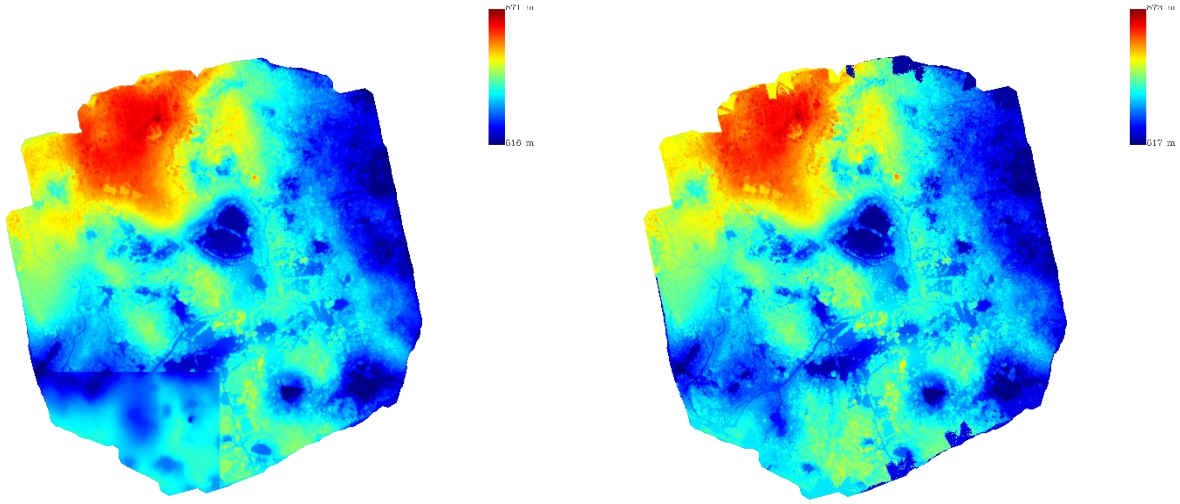


Figure 1. Comparison of DEM (left) and DSM (right) generated from UAV-LiDAR survey

References

Idrizi, B., Pashova, L., Kabashi, I., Mulic, M., Krdzalic, D., Tutic, D., Vucetic, N., Kevic, K., Nikolic, G., & Djurovic, R. (2018). Study of length differences from topography to map projection within the state coordinate systems for some countries on the Balkan Peninsula. In Proceedings of the FIG Congress 2018. https://www.fig.net/resources/proceedings/fig_proceedings/fig2018/papers/ts08e/TS08E_idrizi_pashova_et_al_9602.pdf

Idrizi, B. (2021). Redefining of “EPSG” and “PROJ” for current State Coordinate Reference System of the Republic of North Macedonia. *Proceedings of the International Cartographic Association, 4,* 45. https://doi.org/10.5194/ica-proc-4-45-2021

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957448

The role of coordinates in border diplomacy: The case of Albania

Anduel Cauli [a,*], Pal Nikolli [b], Oltion Pupi [c]

[a] *Head of Cartographic Section in Military Geographic and Infrastructure of Albania, anduelcauli@yahoo.com*
[b] *Prof. Dr. Department of Geography, University of Tirana, Albania, palnikolli@yahoo.com*
[c] *Pedagogue in University of Elbasan, Albania, oltionpupi@gmail.com*

* Anduel Cauli, *anduelcauli@yahoo.com*

Keywords: Border diplomacy, geodetic coordinates, Albania, maritime boundaries, demarcation, geospatial technology, standardization.

Abstract:

This study addresses the essential importance of geodetic coordinates in border diplomacy, focusing on the case of Albania. State borders represent not only geographical divisions, but also sovereignty, national identity, and economic interest. In regions with complex histories, such as the Balkans, any technical discrepancy can have major political and legal consequences.

Geodetic coordinates function as a "neutral language" of border diplomacy, standardizing and verifying territorial space. For Albania, its strategic position and both land and maritime borders have required a careful geodetic and diplomatic approach. The 2009 maritime agreement with Greece and its annulment by the Constitutional Court illustrate how discrepancies in geodetic datum can escalate into political conflict. Similarly, demarcation processes with Montenegro, Kosovo, and North Macedonia show that harmonization of systems and international standardization are essential to avoiding tensions.

This paper examines the theoretical and legal framework for the use of coordinates, including the importance of geodetic datum such as ALB86, KRGJSH2010, and international standards like WGS84/ETRS89. The analysis shows that inaccurate transformations can cause significant displacements and differing interpretations of the border line, turning a technical issue into a diplomatic one. Furthermore, international jurisprudence has recognized the importance of coordinates as legal evidence in border cases, as demonstrated in cases such as *Qatar vs. Bahrain (2001)* and *Nicaragua vs. Honduras (2007)*.

The case of Albania highlights that:

- Coordinates are a strategic diplomatic tool, not just a technical instrument.
- Standardizing coordinate systems and integrating with international networks (EUREF, ITRF) increases credibility and prevents conflict.
- Technical cooperation between parties and transparent documentation of geodetic transformations are essential for negotiating land and maritime borders.
- Modern technologies (GNSS, GIS, LiDAR) improve precision but cannot replace political and legal consensus.

Ultimately, Albania serves as a case study for the Balkans: accurate coordinates and technical-diplomatic harmonization are crucial for border management, regional stability, and progress toward European Union integration. This study proposes that the use of unified coordinate systems, transparent documentation, and collaboration between geodetic experts and negotiators can strengthen border diplomacy and reduce political tensions.

References

ASIG (2020). Agjencia Shtetërore e Informacionit Gjeohapësinor – Raporti Vjetor 2020. Tiranë: ASIG.

Buzuku, A. (2011). Demarkacioni i kufirit Shqipëri–Mal i Zi: Analiza teknike dhe politike. Tiranë: Instituti i Studimeve Gjeopolitike.

Bugajski, J. (2019). The Balkans: A Technical and Political Overview. Washington DC: CSIS Press.

Featherstone, W.E. & Vaníček, P. (1999). Geodetic Datum Transformations: Principles and Practices. Journal of Geodesy, 73(9), pp. 439–449.

Glassner, M.I. & Fahrer, P. (2004). Mapping and Diplomacy: Geospatial Tools in Border Negotiations. New York: Springer.

Gjykata Kushtetuese e Shqipërisë (2010). Vendimi mbi marrëveshjen detare Shqipëri–Greqi. Tiranë: Arkivi i Gjykatës.

Hofmann-Wellenhof, B., Lichtenegger, H. & Collins, J. (2001). GPS: Theory and Practice. 5th ed. Wien: Springer.

Prescott, J.R.V. (2015). The Politics of Borders: Geodesy and International Relations. London: Routledge.

Seeber, G. (2003). Satellite Geodesy: Foundations, Methods, and Applications. Berlin: Walter de Gruyter.

Tanaka, Y. (2015). The International Law of the Sea. Cambridge: Cambridge University Press.

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957483

Geodetic Reference Systems and Map Projections in Bulgaria: Historical Context and Modern Applications

Lyubka Pashova [a,*]

[a] *National Institute of Geophysics, Geodesy and Geography - Bulgarian Academy of Sciences, lpashova@geophys.bas.bg*

* Lyubka Pashova, *lpashova@geophys.bas.bg*

"Concepts are the nodal points of our knowledge."
Acad. Vladimir Hristov

Keywords: Geodetic datum, Geodetic Reference System, Height system, Map projection, BGS'2005

Abstract:

The significant advancements in modern geodetic technologies over recent decades necessitate a reassessment of geodetic coordinate systems. These systems should enhance 3D positioning accuracy, provide direct access to the national reference geodetic coordinate system for a wide range of users, and effectively leverage geospatial information for various applications that rely on a geodetic foundation. Many countries around the world have modernized their Geodetic Reference Systems (GRS) and networks, implementing them in practice using advanced geodetic satellite and ground-based systems, as well as measurement, information, and communication technologies and tools (e.g., Yovev, 2007; 2008).

This document presents a brief historical overview of the coordinate, height, and map projection systems used in Bulgaria since the late 19th Century. From the beginning of the 20th Century to the present, several geodetic reference systems and related height and gravity systems have been implemented, with practical application taking anywhere from several years to a decade. The astronomical-geodetic, leveling, and gravimetric networks developed over the years serve as the infrastructure through which the corresponding coordinate, height, and gravimetric systems are established and disseminated over specific territories. Historically, Bulgaria's mapping efforts began at the end of the 19th Century with the Russian triangulation in the Walbeck 1875 system (Kovács and Timár, 2009). Subsequently, geodetic science and practice in Bulgaria followed global trends in its development, adopting and introducing contemporary geodetic reference coordinate and elevation systems and cartographic projections. The Hayford ellipsoid, the Baltic height system, and the Gauss-Krüger coordinates for a three-stripe map projection were adopted in the 1930s (Yovev, 2003).

In the mid-20th Century, the Karsovski ellipsoid and the 1950 system were introduced, along with a Gauss-Krüger map projection with 3- and 6-degree stripes and the Black Sea height system. For civil purposes, the 1970 coordinate system was adopted in the late 1960s and early 1970s by order of the State Defense Committee in 1969. This system is a type of projection coordinate system from the class of conic projections. Despite Bulgaria's relatively small territory, four Lambert map zones were defined, and geodetic and cartographic products prepared in this system are still utilized today. Additionally, local geodetic projections were used to map major cities, such as Sofia and Plovdiv, to minimize image distortions. Following the alignment of the Unified Astronomical and Geodetic Network of the Eastern European socialist countries, a system from 1942/1983 was also introduced. This system used the Krasovski ellipsoid and the Baltic height system with normal heights, with mapping conducted in 3- and 6-degree Gaussian stripes using the Gauss-Krüger map projection (Yovev, 2003).

The National Geodetic Reference System comprises geodetic datums, reference frames, and physical realizations (such as networks of survey monuments, continuously operating GNSS stations, and gravity measurements) that define the position (latitude, longitude, height), gravity, and orientation of points on, above, or below the Earth's surface across national territory. The transitions between different reference, coordinate, and height systems have been scientifically justified and thoroughly prepared. Global and European practices in modernizing geodetic systems have prompted changes in the structure and functions of high-precision state geodetic networks, aligning with international standards. By the end of the 1990s, Bulgarian geodetic theory and practice had amassed considerable experience in establishing continental and national geodetic networks and their respective reference systems. Bulgaria's state geodetic networks have been created, maintained, and updated using the latest methods, technologies, and instruments.

Following the democratic changes in 1989, the geodetic community organized a special conference in Bulgaria in 1994, during which extensive discussions took place on the introduction of new geodetic reference and height systems.

Decisions were made to implement these systems. Over the past three decades, Bulgarian scientific teams have participated in numerous European and international projects, including EUPOS (http://monitoringeupos.gku.sk/), CERGOP 1/2, CEGRN (http://sgo.fomi.hu/cegrn/), WEGENER-MEDLAS, and INCO-COPERNICUS. Similar research and application projects have been initiated by the International Association of Geodesy (IAG), various international organizations and unions, as well as consortia that include private companies.

Several years after the 1994 conference, the Bulgarian Geodetic System BGS'2000 was introduced by Decree No. 154 of the Council of Ministers of the Republic of Bulgaria on June 4, 2001. This decree defined the parameters and characteristics for global and European geodetic reference and coordinate systems, such as GRS80, EUREF, and ETRF89, as well as for European leveling and gravimetric networks, including UELN and UNIGRACE. The Lambert projection was designated for all civil applications, and a world layout of map sheets, including those at a scale of 1:2000, was incorporated. However, BGS'2000 has never been implemented. During the process of introducing a new Geodetic Reference System in the country from 1995 to 2016, several regulatory documents were created and published, including instructions, ordinances, and training manuals.

After some years, the Council of Ministers introduced the Bulgarian Geodetic System 2005 (BGS 2005) through Decree № 153 on July 29, 2010, and Ordinance № 2 on July 30, 2010. This new system replaced GRS'2000 and maintained the same basic geodetic parameters. The BGS 2005 includes three reference systems: 1. Coordinate System 2005: Based on the 2005.0 epoch of ETRS89, it uses GRS80 parameters and relies on the State GPS network connected to the EPN; 2. Vertical Reference System 2005: Established using the First Order State Leveling Network and points from the EUNV-DA project, linking to EVRF2007 with data from IGSN71; 3. Gravimetric Reference System IGSN71: Defined by the UNIGRACE project (2005) and realized through the National Gravimetric Network. The primary cartographic projection for Bulgaria is the Universal Transverse Mercator (UTM) projection, divided into zones 34N and 35N. The second zone covers most of the country, as per Instruction № RD-02-20-12 on August 3, 2012. Deformations increase progressively beyond ±30 from the central meridian, with a scale factor of m = 0.9996. Due to the UTM projection's limitations for practical applications, the "Cadastral Coordinate System 2005" was implemented through Ordinance No. RD-02-20-5 on December 15, 2016. This system utilizes a Lambert Conformal Conic projection designed to minimize distortion across Bulgaria. The GCCA offers a free program, BGSTrans 4.6 (AGCC; https://www.cadastre.bg/), for converting between geodetic coordinate systems. Additionally, information on Bulgaria's official geodetic systems has been added to the Information System for European Coordinate Reference Systems (CRS-EU) (https://www.crs-geo.eu/) and the EPSG public registry (https://epsg.io/?q=Bulgaria), allowing for coordinate transformations with an accuracy of ±1 m.

When introducing a new geodetic reference and coordinate system, selecting an appropriate map projection is crucial to minimizing distortion within the state's territory. For large areas mapped on small scales, Universal Transverse Mercator (UTM) and Lambert Conformal Conic projections are recommended. Parameters of the chosen projection, including the central meridian, the latitude of the origin, and the scale factor, must be aligned to ensure an optimal depiction with minimal deformation. It is also important to use official transformation parameters in geodetic software or GIS tools, such as QGIS or ArcGIS, to achieve accuracy. GRS provides accurate, interoperable positioning for diverse users, from smartphone navigation to advanced Earth monitoring. These systems should be regularly maintained and updated in line with advancements in geodetic science (UN-GGCE, 2025).

References

Idrizi, B., Pashova, L., Kabashi, I., Mulic, M., Krdzalic, D., Tutic, D., Vucetic, N., Kevic, K., Nikolic, G., & Djurovic, R. (2018). Study of length differences from topography to map projection within the state coordinate systems for some countries on the Balkan Peninsula. In: Proceedings of the FIG Congress 2018. https://www.fig.net/resources/proceedings/fig_proceedings/ fig2018/papers/ts08e/TS08E_idrizi_pashova_et_al_9602.pdf (accessed on October 17, 2025)

Kovács, B., Timár, G. (2009). The Austro-Hungarian Triangulations in the Balkan Peninsula (1855–1875). In: Gartner, G., Ortag, F. (eds) Cartography in Central and Eastern Europe. Lecture Notes in Geoinformation and Cartography. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-03294-3_35

UN-GGCE (2025). The Roadmap. Guidance on how to build a country's Geospatial Reference System. Ver.0.1, Available at: https://ggim.un.org/UNGGCE/ (accessed on October 12, 2025)

Yovev, I. (2003). The State Geodetic Networks of Bulgaria and the Related Reference, Coordinate and Height Systems. *Geodesy*, BAS, 16, 101–141. (In Bulgarian)

Yovev, I. (2007). GPS technologies and provision for their effective application in Bulgaria(Part I), Geography, 4, 3-10, http://prokarstterra.bas.bg/geo21/2007/4-07/pp3-10.html, (In Bulgarian)

Yovev, I. (2008). GPS technologies and provision for their effective application in Bulgaria (Part II), Geography, 5, 12-20, http://prokarstterra.bas.bg/geo21/2007/5-07/12-20.pdf (In Bulgarian)

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957560

From EPSG 2462 to EPSG 6870: The evolution of coordinate systems in Albania and the importance of KRGJSH 2010 for National Geospace

Pal Nikolli [a], Sonila Sinjari[*a], Xhulia Bygjymi [a], Denisa Kukaj [b]

[a] *University of Tirana, Geography department, pal.nikolli@fhf.edu.al, sonila.xhafa@fhf.edu.al, xhulia.bygjymi@fhf.edu.al*
[b] *State Authority of Geospatial Information, denisakukaj@gmail.com*

* Sonila Sinjari, *sonila.xhafa@fhf.edu.al*

Keywords: Coordinate reference systems, EPSG 2462, EPSG 6870, KRGJSH2010, ETRS89, GRS80, geodesy, digital cartography, GIS, geodetic transformations, ASIG, national geospatial infrastructure, GNSS, Transverse Mercator, spatial standardization

Abstract:

The evolution of coordinate reference systems in Albania reflects a profound technical, institutional, and strategic transformation, marking the transition from a locally derived legacy system (EPSG:2462 – Albanian 1987 / Gauss–Krüger zone 4) to a modern, harmonized geospatial framework aligned with European and global standards (EPSG:6870 – ETRS89 / Albania TM 2010). The former system, based on the Krasovsky 1940 ellipsoid, served national cartography, geodesy, and infrastructure development for several decades; however, it exhibited notable limitations related to GNSS compatibility, planimetric distortions, and restricted interoperability with international geospatial datasets.

The establishment of the Albanian Geodetic Reference Framework 2010 (KRGJSH2010) and the adoption of EPSG:6870—built upon the GRS80 ellipsoid and the ETRS89 datum—represent a fundamental modernization of the national geodetic infrastructure. This transformation enables higher positional accuracy, improved institutional interoperability, compliance with the European Spatial Data Infrastructure (ESDI), and seamless integration into continental geodetic networks.

This study presents a comparative analysis of the technical parameters of both systems, including Transverse Mercator projection characteristics, false origins, scale factors, and their effects on planimetric coordinates. It further examines the institutional guidelines issued by ASIG for the operationalization of the new system, the challenges associated with transforming historical datasets, and the practical implications for GIS applications, digital cartography, urban planning, land administration, environmental monitoring, and engineering design. The findings indicate that the adoption of EPSG:6870 substantially reduces positional discrepancies, strengthens spatial integrity, and standardizes geospatial workflows across Albania, thereby supporting the development of a robust and interoperable national geospatial infrastructure.

The study recommends enhancing professional capacities for geodetic transformations, ensuring controlled and well-documented migration of legacy datasets, investing in the National Spatial Data Infrastructure (NSDI), and promoting the adoption of international geospatial standards. Ultimately, the transition to EPSG:6870 constitutes a strategic advancement for Albania, significantly improving the quality, accuracy, and interoperability of geospatial information while aligning the country with contemporary European best practices in geodesy and cartography.

Establishing new CRS inside Europe: practical considerations

Javier Jimenez Shaw [a]

[a] *PROJ Contributor, SRS team at Pix4D*

* Javier Jimenez Shaw, *javier.shaw@pix4d.com*

Keywords: Coordinate Reference System (CRS), Open Data & Open Source, EPSG Registry

Abstract:

North Macedonia is considering defining a new Coordinate Reference System for the country, modernizing an old one more than hundred years old.

This talk shows the different meaningful alternatives you can choose and expresses a recommendation. This analysis is done after looking at several countries and their actual usage of modern or old CRSs.

As PROJ.org contributor, it insists in the Open Source and Open Data importance in geodesy and cartography. Have open and free access to data and transformations make all the geography process more transparent. Specially in cadastral data.

EPSG serves as as a common registry for this information, making it freely available to users and software developers.

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957598

Assessment of the Kosovo National Coordinate System (KOSOVAREF01) and Evaluation of Alternative Systems

Fitore Bajrami Lubishtani[a], Milot Lubishtani [b]*, Pal Nikolli[c], Bashkim Idrizi[a]

[a] *University of Prishtina, Faculty of Civil engineering, Geodesy department, fitore.bajrami@uni-pr.edu, bashkim.idrizi@uni-pr.edu*
[b] *Geo Noar Ferizaj, milot.lubishtani1@hotmail.com*
[c] *University of Tirana, palnikolli@yahoo.com*

* Milot Lubishtani, *milot.lubishtani1@hotmail.com*

Keywords: CRS, Kosova, Kosovaref01, map projections

Abstract:

Coordinate Reference Systems (CRSs) provide the mathematical framework for defining the locations of spatial entities within a reference frame, which includes a geodetic datum and, in many cases, a map projection and additional parameters. In practice, the term Spatial Reference System (SRS) is often used interchangeably with CRS. Each CRS is linked to a local or global datum and defines a specific domain of validity within which the relationship between coordinates and physical locations can be reliably maintained. National mapping agencies are responsible for selecting appropriate map projections and their corresponding geodetic reference systems.

The Republic of Kosova, located in Southeast Europe, adopted its national CRS, KOSOVAREF01, in 2001, based on the ETRS89 geodetic datum. Prior to this, Kosova used the coordinate system known as FryRef30 (internationally recognized as MGI/Balkan Zone 7), established in 1924 during its inclusion in the former Yugoslav Federation. The principal differences between the old and new systems lie in their respective datums and ellipsoids. When defining the parameters of KOSOVAREF01 between 1999 and 2001, the reference map projection and parameters were derived from FryRef30, obviously without sufficient scientific analysis. This resulted in systematic negative deformations across the entire territory of Kosova. The distortion values range from –10 cm/km along the central meridian to –2.1 cm/km at the westernmost point (Figure 1), with a mean distortion of –8.7 cm/km. Consequently, horizontal distances of 1 km measured on the topographic surface are reduced on the map by an average of –22.13 cm/km, with values ranging from –50.25 to –12.86 cm/km (Figure 2).

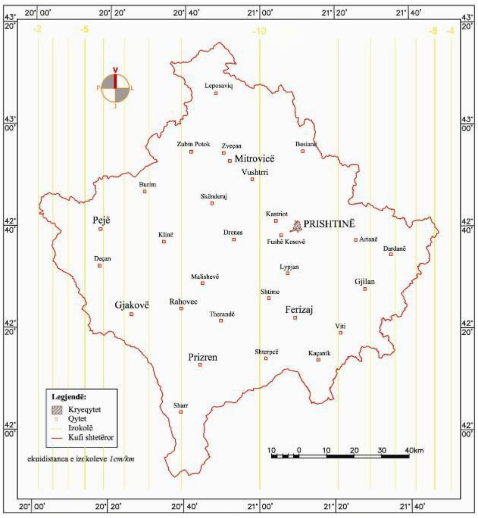
Although KOSOVAREF01 was introduced in 2001, it was not officially registered in the EPSG database until April 2019, when change request EPSG 2019.042 was accepted, assigning nine EPSG codes to Kosova's national CRS.

To evaluate alternative projections suitable for Kosova's territory, several CRS configurations were tested. The Gauss–Krüger projection with scale factors 0.99996 and 0.999967, as well as a tangential variant without negative deformations, were analyzed. With a scale factor of 0.99996, deformations range from –4 to +3.9 cm/km, with a mean of 2.93 cm/km over the national territory and 3.06 cm/km in urban areas. The variant with a scale factor of 0.999967 produces deformations between –3.3 and +4.6 cm/km, with a mean of 2.46 cm/km overall and in cities. The tangential case yields improved uniformity, with deformations between 0 and +7.9 cm/km, and mean values of 1.3 cm/km across the country and 0.96 cm/km in cities.

In the stereographic tangential projection, all distortions are positive, ranging from 0 to +4.18 cm/km, with mean values of 1.17 cm/km for the national area and 0.9 cm/km in cities. Two extended variants were also tested, using negative central deformations of –2.1 cm/km (scale factor 0.999979) and –1.9 cm/km (scale factor 0.999981). The first yielded deformation intervals of –2.1 to +2.08 cm/km, with mean values of 1.08 cm/km nationwide and 1.21 cm/km in cities, while the second resulted in –1.9 to +2.28 cm/km, with averages of 0.94 cm/km and 1.07 cm/km, respectively.

In the Lambert Conformal Conic projection, the tangential case produced deformations between 0 and +7.69 cm/km, with mean values of 1.15 cm/km across the country and 0.9 cm/km in cities. Introducing a negative central deformation of –3.8 cm/km (scale factor 0.999962) yielded deformation intervals from –3.8 to +3.89 cm/km, with mean values of 2.85 cm/km nationally and 2.95 cm/km in cities.

Because of the relatively small area of Kosova, the UTM projection introduces substantial distortions, ranging between –32.11 and –40 cm/km, with mean values of 38.7 cm/km nationwide and 39.04 cm/km in cities.



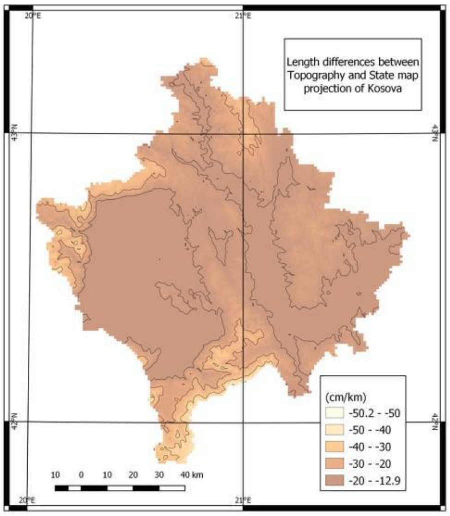


Figure 1. Map deformations in KOSOVAREF01.

Figure 2. Length differences between topography and map projection in KOSOVAREF01

References

Bajrami, F. (2008). Projecting of Republic of Kosova in the Gauss Kruger projection (Diploma thesis). Geodesy Department, Faculty of Civil Engineering, University of Prishtina, Prishtina, Kosova.

Lubishtani, M. (2008). Alternative variants of the state map projection of the Republic of Kosovo (Diploma thesis). Geodesy Department, Faculty of Civil Engineering, University of Prishtina, Prishtina, Kosova.

Idrizi, B., Bajrami, F., & Lubishtani, M. (2009). Projecting of territory of the Republic of Kosova in several most used state map projections. FIG WW 2009. https://www.fig.net/resources/proceedings/fig_proceedings/fig2009/papers/ts04c/ts04c_idrizi_bajrami_lubishtani_3350.pdf

Bajrami, F. (2012). Relations between referent systems FRYREF30 and KOSOVAREF01 (Master thesis). Geodesy Department, Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania.

Idrizi, B. (2014). Length differences between topography and map projections; case study: country area of Macedonia. Proceedings, 5th International Conference on Cartography and GIS, Riviera, Bulgaria. https://cartography-gis.com/proceedings/5ICCGIS_Proceedings_Vol1_2-HQ.pdf

Idrizi, B., Pashova, L., Kabashi, I., Mulic, M., Krdzalic, D., Tutic, D., Vucetic, N., Kevic, K., Nikolic, G., & Djurovic, R. (2018). Study of length differences from topography to map projection within the state coordinate systems for some countries on the Balkan Peninsula. Proceedings of the FIG Congress 2018. https://www.fig.net/resources/proceedings/fig_proceedings/fig2018/papers/ts08e/TS08E_idrizi_pashova_et_al_9602.pdf

Idrizi, B. (2020). International EPSG coding of the state coordinate reference system of the Republic of Kosova. Proceedings Vol. 1, 8th ICCandGIS, June 2020, Nessebar, Bulgaria. https://cartography-gis.com/proceedings/8ICCGIS_Proceedings_Vol1_2020-LQ.pdf

Idrizi, B. (2023). State Coordinate Reference Systems of the Republic of Kosova and the Republic of North Macedonia in international EPSG and PROJ databases. 2nd International Conference of Civil Engineering – ICCE 2023, Tirana, Albania. https://www.icce2023.al/abstracts-and-papers

Lubishtani, F. B., Idrizi, B., Lubishtani, M. (2020). Developing multiband raster database for utilization of global Earth gravimetrical models for the Republic of Kosova. Proceedings Vol. 1, 8th ICCandGIS, June 2020, Nessebar, Bulgaria. https://iccgis2020.cartography-gis.com/8ICCGIS-Vol1/8ICCGIS_Proceedings_Vol1_(49).pdf

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17957618

Modernised transformation between the old Dutch national CRS and ETRS89

Jochem Lesparre [a,*], Lennard Huisman [a]

[a] *Kadaster, jochem.lesparre@kadaster.nl, lennard.huisman@kadaster.nl*

* Jochem Lesparre, *jochem.lesparre@kadaster.nl*

Keywords: CRS, GIS, geodesy, mapping, standardisation

Abstract:

There are two ways to modernise a national projected (or state plane) coordinate reference system. The first option is to introduce a new coordinate reference system (CRS). A new, homogeneous national CRS allows straightforward transformation to and from a regional or global CRS. However, the transition to a new national CRS or working with multiple CRSs is complex for many end users of geo-information and professionals from other fields that do surveying or their own GIS data collection, like civil engineering, archaeology, biology, and national statistics.

The second option is to modernise the transformation procedure between the existing national CRS and a homogeneous GNSS-based regional or global CRS. Some national CRSs lack a precise transformation in the EPSG geodetic parameter dataset. This complicates CRS use, as most software only support transformations included in the EPSG dataset. The problem of including the transformation of a national CRS in EPSG is often not the complexity of the CRS. The transformation of any old CRS can be modernised if the distortions in the CRS are spatially correlated and smooth, and if enough data points are available to estimate a distortion correction model and the datum transformation. Furthermore, the scale of the national CRS should be close to 1 and the used map projection must be commonly supported by software.

For example, the over a century old national CRS of the Netherlands was redefined as a transformation of ETRS89 in 2000. This transformation was implemented exactly by the surveying community but not by the GIS community, resulting in inconsistencies of up to 0.25 metre. During a user consultation project between 2014 and 2018, switching to ETRS89 or an ETRS89-based projection was considered. However, the projections for ETRS89 recommended by INSPIRE were found unsuitable as a single national projection. Furthermore, to enable users to migrate their data to a new national CRS, a precise transformation from the existing national CRS to ETRS89 is needed in GIS software. Therefore, the official transformation procedure to ETRS89 was redesigned instead of introducing a new CRS. This new definition of the national CRS is now included in EPSG (IOGP, 2025) and supported by GIS software. It gives within 0.01 metre the same results as the previous official transformation (Lesparre et al., 2022).

With this modernised transformation, users of the surveying and GIS communities can transform between the national CRS and ETRS89 without losing accuracy. As a result, there is no current demand for a new national CRS and no need for a costly and long transition to a new national CRS. The existing national CRS effectively functions as a projection of ETRS89.

This case demonstrates that modernising a national projected CRS does not necessarily require introducing a new CRS.

References

IOGP. (2025, September 16). *Amersfoort to ETRS89 (9).* The EPSG Geodetic Parameter Dataset. https://epsg.org/transformation_9282/Amersfoort-to-ETRS89-9.html

Lesparre, J., Huisman, L., Alberts, B., & De Ligt, H. (2022, June 27). *RDNAPTRANS2018: Coordinate transformation to and from Stelsel van de Rijksdriehoeksmeting and Normaal Amsterdams Peil*. NSGI. https://www.nsgi.nl/coordinatenstelsels-en-transformaties/coordinatentransformaties/rdnap-etrs89-rdnaptrans

Geo Information

Special issue – Book of Abstracts

DOI: 10.5281/zenodo.17957633

State Plane Coordinate Systems of North Macedonia

Bashkim Idrizi [a]

[a] *University of Prishtina, Faculty of Civil Engineering, Geodesy department, bashkim.idrizi@uni-pr.edu, bashkim.idrizi@yahoo.com*

* Bashkim Idrizi, *bashkim.idrizi@yahoo.com*

Keywords: North Macedonia, EPSG, CRS, ETRS89, Gauss-Kryger projection, Bessel 1841, Hermannskogel datum

Abstract:

The coordinate reference system (CRS) of North Macedonia constitutes a hybrid legacy of the former Yugoslav geodetic framework, founded on the Hermannskogel datum, Bessel 1841 ellipsoid, and Gauss–Krüger projection with a central meridian of 21°E. Despite multiple legal and regulatory updates, the country continues to operate simultaneously with three coordinate systems—EPSG:6204, EPSG:6316, and EPSG:9945—which differ in their treatment of false eastings and northings. These inconsistencies generate systematic offsets of 7,000 km (E) and 4,000 km (N), producing non-transformable datasets and spatial incoherence within national geospatial infrastructures. This study synthesizes the historical, technical, and projectional aspects of the CRS of North Macedonia, examining (I) the legal evolution of state coordinate definitions, (II) the mathematical characterization of its projection variants, and (III) distortions resulting from height-to-projection reductions. Results confirm both large-scale positional offsets and significant ground-to-grid discrepancies, with mean linear deformations of −16.01 cm/km under the current state projection. The findings substantiate the necessity of establishing a new ETRS89-based coordinate system that integrates geodetic accuracy with modern low-distortion projection principles.

Coordinate reference systems (CRSs) provide the mathematical foundation of geospatial positioning by linking four conceptual surfaces: the topographic surface, the sea (geoid) level, the reference ellipsoid, and the map projection plane. The accuracy and interoperability of national spatial data infrastructures depend critically on the internal consistency of this chain. In the Republic of North Macedonia, the currently enforced CRS remains based on the Hermannskogel datum and Bessel 1841 ellipsoid, initially introduced by the Military Geographic Institute (MGI) in Belgrade in the early 20th Century. The legal definition, codified as EPSG:6204, prescribes a Gauss–Krüger projection with a central meridian at 21°E and a false easting of 500,000 m (Official Gazette No. 55/2013). However, institutional practice diverges sharply: the Agency for Real Estate Cadastre (AREC) and National Spatial Data Infrastructure (NSDI) geoportals disseminate data predominantly in EPSG:6316, while first digitized cadastral products rely on the truncated coordinate form EPSG:9945.

The analysis confirmed systematic offsets between the three CRS realizations: approximately +7,000 km in easting between EPSG:6204 and 6316, and +4,000 km in northing between EPSG:6204 and 9945. Although AREC officially recognizes EPSG:6204, its operational data remain encoded in EPSG:6316. The truncated CRS (EPSG:9945) emerged during the digitization of cadastral archives, introducing a false northing of –4,000,000 m. These discrepancies produce incompatible coordinate domains that cannot be transformed without explicit definition of datum parameters. Default PROJ transformations apply low-accuracy regional parameters, yielding up to 10 m of horizontal displacement. Adoption of the high-precision parameters defined in EPSG:6206 would mitigate this error.

This coexistence of three CRSs—each internally valid but mutually offset—has created a unique geodetic situation. Misaligned datums, inconsistent transformation parameters, and the absence of uniform EPSG/PROJ definitions have collectively reduced spatial interoperability and impaired the accuracy of coordinate transformations to WGS84 and ETRS89. As a result, overlays of national datasets with global basemaps reveal planimetric shifts exceeding 10 m. The scientific objective of this study is to evaluate the structural causes and projection-induced distortions of the existing CRS and to outline the conceptual foundations for an ETRS89-based state plane system for North Macedonia.

A multi-layered analytical framework was employed, integrating legal-historical, geodetic-technical, and projectional components.

Legal-historical review: National legislation and regulations (Official Gazette Nos. 34/1972, 55/2013, 151/2013, 159/2013) were analyzed to trace the evolution of state coordinate definitions and their relationship to MGI conventions.

Geodetic registry analysis: CRS definitions and transformation parameters were examined from EPSG (codes 6204, 6316, 9945) and PROJ repositories, including Bursa–Wolf seven-parameter transformations (EPSG:6205, 6206). Comparative inspection identified inconsistencies in area extents, false eastings, and PROJ string definitions.

Projection-distortion modelling: Quantitative evaluation was performed on a 1 km national grid comprising 25,635 points. Elevations from ASTER GDEM and geoid undulations from EGM08 were used to compute successive reductions (topographic → geoid → ellipsoid → projection) following classical geodetic reduction formulas. Three projection configurations were tested: UTM Zone 34N (k=0.9996), Gauss–Krüger 21°E (k=0.9999, official), and Modified Gauss–Krüger 21°45′E (k=0.99993, optimized). The distortions were evaluated as linear deformation ΔL/L per kilometre, and visualized through raster interpolation in QGIS.

Table 1. Parameters of current CRS variants and corresponding offsets.

UTM – zone 34N	**Gauss-Kruger (21°E, 0.9999)**	**Gauss-Kruger (21°45'E, 0.99993)**
Central meridian: 21° Origin of latitude: Equator Scale factor: 0.9996 False easting: 500000m False northing: 0m	Central meridian: 21° Origin of latitude: Equator Scale factor: 0.9999 False easting: 500000m False northing: 0m	Central meridian: 21°45' Origin of latitude: Equator Scale factor: 0.99993 False easting: 500000m False northing: 0m

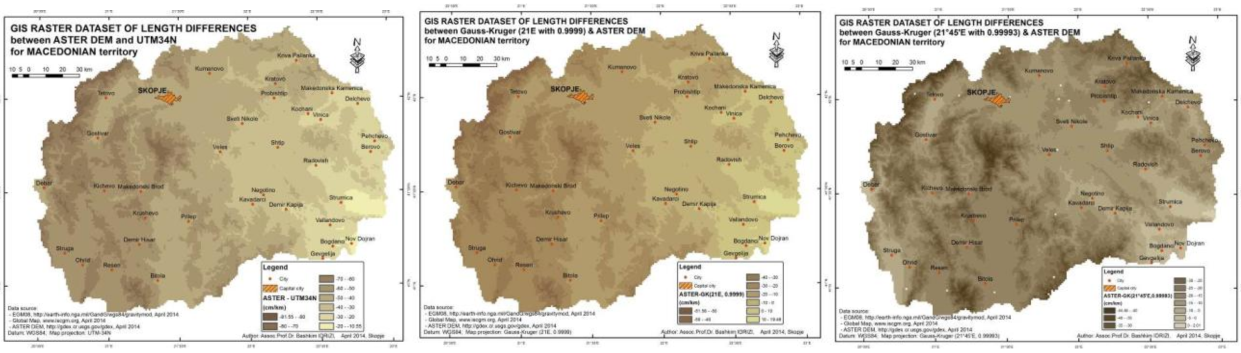


Figure 1. Spatial model of topography-to-projection reductions across North Macedonia (1 km grid resolution).

Table 2. Progressive length differences of 1km lengths between ASTER and five reference surfaces

SURFACES	**ASTER DEM – EGM08**	**ASTER DEM – WGS84**	**ASTER DEM – UTM 34N**	**ASTER DEM – Gauss-Kruger (21°E, 0.9999)**	**ASTER DEM – Gauss-Kruger (21°45'E, 0.99993)**
Θ	-13.03cm/km	-13.74cm/km	-46.01cm/km	-16.01cm/km	-17.17cm/km
Dispersion of distortions	-0.38 to -41.43cm/km	-1.07 to –42.11cm/km	-10.55 to -81.55cm/km	-51.56 to 19.48cm/km	-44.46 to 2.01cm/km
***d* positive**	-	-	-	11.32%	0.09%
***d* negative**	100%	100%	100%	88.62%	99.9%
***d* without distortions**	-	-	-	0.06%	0.01%

Successive reduction modelling revealed mean cumulative distortions of −46.01 cm/km for UTM 34N, −16.01 cm/km for the official Gauss–Krüger, and −17.17 cm/km for the modified Gauss–Krüger projection. The distribution of distortions is topographically dependent: negative contractions dominate in the high-altitude west (Šar Planina, Mavrovo), whereas minor positive expansions occur in eastern lowlands. These results confirm that the current state projection is not a low-distortion projection (LDP), as its parameterization was optimized at the ellipsoid rather than at mean terrain height. Application of root-mean-square (RMS) minimization methods or constant-height conformal projections could reduce average distortion below 5 cm/km.

As geospatial interoperability becomes central to EU spatial policy, harmonization toward ETRS89 is no longer optional but a strategic requirement. From a geodetic and cartographic standpoint, modernization should proceed through three interrelated steps:

- Datum modernization: adoption of ETRS89 with GRS80 ellipsoid as the new geodetic reference frame,

- Projection optimization: derivation of a national Low-Distortion Projection (LDP) based on RMS-minimization principles, possibly within a Transverse Mercator or Lambert Conformal Conic configuration tailored to mean terrain height, and
- Institutional integration: submission of a new CRS definition to EPSG, coordinated by AREC and academia, ensuring interoperability with European Spatial Data Infrastructure (SDI) frameworks and compliance with ISO 19111 and OGC standards.

The creation of a unified State Plane Coordinate System of North Macedonia (SPCS–NM) would eliminate legacy inconsistencies, enhance accuracy for engineering and cadastral applications, and align the national geodetic infrastructure with the European spatial reference environment.

Acknowledgement

This article is based on results from the National Scientific Project “State Plane Coordinate Reference System of the Republic of North Macedonia” (DOI: 10.17605/OSF.IO/MPUHG), publicly accessible at www.scrsproject.mk. The author gratefully acknowledges the South-East European Research Institute on Geo Sciences and all project partners for their valuable collaboration and for granting permission to use project data in this publication. The article will also be referenced on the project’s official website following its publication. *https://www.scrsproject.mk*

References

Idrizi, B. and Ribarovski, R. (2010). Historical overview, quality and current condition of the geodetic networks in Macedonia. *FIG Working Week Proceedings*, April 11-16, 2010, Sydney, Australia. https://www.fig.net/resources/proceedings/fig_proceedings/fig2010/papers/ts01h/ts01h_idrizi_ribarovski_4242.pdf

Idrizi, B. (2015). Developing raster datasets for length differences between topography, geoid, ellipsoid and map projection for macedonian territory. *FIG WW 2015 Proceedings*. https://www.fig.net/resources/proceedings/fig_proceedings/fig2015/papers/ts04d/TS04D_idrizi_7798.pdf

Idrizi, B. Pashova, L. Kabashi, I. Mulic, M. Krdzalic, D. Tutic, D. Vucetic, N. Kevic, K. Nikolic, G. Djurovic, R. (2018). Study on length differences from topography to map projection within the state coordinate systems for some countries on the Balkan Peninsula. FIG Working Week 2018. Istanbul. Turkey. https://fig.net/resources/proceedings/fig_proceedings/fig2018/papers/ts08e/TS08E_idrizi_pashova_et_al_9602.pdf

Idrizi, B. (2014). Length differences between topography surface and map projections: Case study of the country area of Macedonia. In Proceedings of ICC-GIS 2014 (pp. 154–163). https://cartography-gis.com/docsbca/5ICCandGIS_Proceedings.pdf

Idrizi, B. (2019). Harmonization of different type of coordinate systems used for North Macedonian official spatial data. Proceedings of the International Cartographic Association, 2, 46. https://doi.org/10.5194/ica-proc-2-46-2019

Idrizi, B. (2021). Redefining of “EPSG” and “PROJ” for current State Coordinate Reference System of the Republic of North Macedonia. Proceedings of the International Cartographic Association, 4, 45. https://doi.org/10.5194/ica-proc-4-45-2021

Idrizi, B. (2023). Current conditions, opportunities and deficiencies of using State Coordinate Reference System of North Macedonia from international EPSG and PROJ databases. Abstracts of the International Cartographic Association, 6, 297. https://doi.org/10.5194/ica-abs-6-297-2023

Institute, G. (2025). National Scientific Project: State Plane Coordinate Reference System - Republic of North Macedonia. https://doi.org/10.17605/OSF.IO/MPUHG https://www.scrsproject.mk/p/references.html

Official Gazette No. 55. Year 2013. Law for real estate cadaster. Agency for real estate cadaster. Skopje. North Macedonia. https://www.katastar.gov.mk/wp-content/uploads/Regulativa/zakoni/zakoni/Zakon%20za%20KN%202013.pdf

Official Gazette No. 151. Year 2013. Regulation for basic geodetic works. Agency for real estate cadaster. Skopje. North Macedonia. https://www.katastar.gov.mk/wp-content/uploads/Regulativa/Pravilnici/osnovni%20geodetski%20raboti.pdf

ISSN: 1857-9000, EISSN: 1857-9019

DOI: 10.5281/zenodo.17703386

Report on the International Scientific Conference

"Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges"

Skopje, October 31, 2025 (*hybrid format*)

Summary

The international scientific conference "Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges", held on October 31, 2025, at Mother Teresa University in Skopje, brought together participants from leading regional cartographic associations and international experts to address the critical establishment of a cutting-edge State Plane Coordinate Reference System (SPCRS) for North Macedonia. Organized by the South-East European Research Institute on Geo Sciences (Geo-SEE Institute), the conference focused on crucial themes such as existing CRS practices, legal frameworks, and implementation challenges. Key outcomes underscored the urgent need for a legally compliant CRS that aligns with European standards (ETRS89/GRS80), robust stakeholder engagement, and a clear transition from research to actionable implementation. The conference not only facilitated vital knowledge exchange but also laid a strong foundation for ongoing collaboration to enhance national geospatial systems, with effective dissemination strategies set to amplify its impactful findings through publications and digital platforms.

1. INTRODUCTION

On October 31 2025, within the framework of the national project "State Plane Coordinate Reference System of the Republic of North Macedonia (SCRS)", the South-East European Research Institute on Geo Sciences (Geo-SEE Institute) in collaboration with eight esteemed international organizations and companies, held an international scientific conference titled *"Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges"*. The event took place at Mother Teresa University in Skopje, with both in-person attendance and online participation available via the following link: https://www.scrsproject.mk/p/international-conference.html.

The Geo-SEE Institute, as the main organizer and under the umbrella of the International Federation of Surveyors (FIG), was strongly supported by the Bulgarian Cartographic Association, the Croatian Cartographic Society, the Kosovo Association of Surveyors, the European Group of Surveyors, and the Macedonian Chamber of Trade Surveying Companies as co-organizers. The event was sponsored by the Alb Matrix Group (Geo Sensors) from Albania and the company FARO Europe.

The primary objective of the conference was to present the key results of the national project, engage international experts, share experiences, discuss methodologies and findings, and explore the future implementation of the proposed coordinate reference system (CRS) for North Macedonia (https://www.scrsproject.mk).

The theme of the conference was focused on the central questions:

- What lessons from existing state plane coordinate reference systems (CRSs) can inform North Macedonia's CRS?
- What legal and institutional frameworks are needed for a new national CRS?
- What technical options ensure accuracy and compatibility with European standards?

- What practical challenges exist in implementing the new CRS?

2. PARTICIPANTS AND FORMAT

The hybrid format enabled participation from local and international stakeholders, including researchers, geospatial professionals, institutional representatives, and policymakers. The project team provided a platform for exchanging knowledge on coordinate reference systems (CRSs) and for dialogue about engineering, legal-institutional, and implementation aspects.

Distinguished presenters from **North Macedonia, Albania, Bulgaria, Croatia, Germany, Greece, Kosovo, the Netherlands, and Türkiye** shared their scientific findings and practical experiences related to state plane coordinate reference systems. The hybrid event attracted a diverse range of participants, including experts, researchers, and institutions working towards harmonizing national geospatial systems with European standards. **In total, 67 participants attended the conference in person and 91 joined online**, demonstrating strong regional and international engagement in this important field.

3. CONFERENCE PROGRAM AND KEY THEMES

The conference covered several themes related to the development of a national state-plane CRS:

- Comparative review of existing state-plane CRS in other countries to identify best practices and their lessons for North Macedonia.
- Legal and institutional issues in establishing a new national CRS to define necessary standards, legislation, and responsibilities.
- Technical/methodological options for the future CRS, including accuracy, compatibility with European/international systems, and ease of use.
- Practical implementation challenges: stakeholder consultations, migration from existing systems, interoperability, EPSG coding, and GIS applications.

These themes align with the work packages of the project (https://www.scrsproject.mk), such as WP3 (Legal Issues) and WP4 (CRS in other countries).

4. KEY OUTCOMES AND MESSAGES

Some of the major outcomes of the conference were:

- A shared recognition of the importance of a modern, accurate, legally-conforming CRS for North Macedonia that aligns with European standards and supports GIS, surveying, mapping, and National Spatial Data Infrastructure (NSDI).
- Good practice examples from other countries were discussed, which will help inform the design of the new system. Insights from other countries highlight the importance of strong institutional frameworks.
- Institutional stakeholders emphasized the need for clear legal mandates, coordination among relevant bodies (surveying, mapping, and geospatial agencies), and training for practitioners. A successful rollout requires careful planning, thorough stakeholder consultation, and effective capacity building.
- Technical options were analyzed: balancing high accuracy and compatibility with usability for national applications.

- Implementation steps were outlined, including stakeholder consultation, migration planning from current systems, pilot tests, capacity building, and dissemination of the project results.
- The project team reaffirmed that the next phase will transition from research to action, focusing on preparing for the adoption of the new CRS, supporting institutions, and ensuring the sustainable use of the system.

5. PUBLICATIONS AND DISSEMINATION

The conference serves as a milestone for disseminating the project's findings and engaging the geospatial community. The project website announced the event and related content. The conference announcement was posted on the GeoSEE website on September 15, 2025, and information about the successfully held conference was published on November 1, 2025.

Following the conference, the GeoSEE Institute will implement a plan to publish a book of abstracts with a Digital Object Identifier (DOI) index and inclusion in the Directory of Open Access Journals (DOAJ). Additionally, presentations will be published on the conference website, ensuring that the conference outputs achieve visibility in international databases.

6. RELEVANCE OF THE CONFERENCE TOPIC

For those working in surveying, large-scale mapping, cadaster, geodesy, engineering geodesy, urban planning, GIS, environmental monitoring, etc., the establishment of a new national state-plane CRS based on ETRS89 datum with GRS80 Earth ellipsoid, and ground to grid map projection, is highly relevant:

- It will provide improved spatial accuracy and consistency across survey, cartography, civil engineering, GIS, and monitoring datasets.
- Aligning national spatial data with a modern reference system and the well-established OGC and ISO geospatial standards enhances interoperability with EU datasets, making cross-border environmental studies more robust.
- Discussions on the institutional and legal framework help contextualize the challenges that may arise in data harmonization, metadata standards, and regulatory compliance.
- Technical insights from the conference can help define the methodology for integrating spatial data from multiple sources (geodetic survey, remote sensing, GIS) and establishing baseline reference systems.

7. RECOMMENDATIONS AND NEXT STEPS

Based on the conference abstracts, presentations, and panel discussions, the following recommendations emerge:

1. **Engage with the project outcomes**: Review the technical options and legal frameworks presented and assess how they align with spatial datasets and GIS workflows.
2. **Prepare for migration**: If the monitoring database currently uses older coordinate systems or local datums, plan for transformation to the future state-plane CRS to ensure consistency.

3. **Capacity building**: Ensure that the team has the appropriate competencies and is familiar with geodetic transformations, datum shifts, projection changes, and metadata documentation - topics that were highlighted at the conference.

4. **Collaboration and feedback**: Actively participate in stakeholder consultation phases, sharing the specific needs of organizations, institutions, or private companies, so that the design of the national system meets these use cases.

5. **Leverage interdisciplinary integration**: The conference demonstrated the value of bringing together surveying/geodesy, cartography/mapping, GIS, legal/institutional, and practical application domains. For the SCRS project, maintaining awareness and seeking feedback on all these dimensions (legal, institutional, technical) is crucial when designing new CRSs.

8. CLOSING REMARKS

The international scientific conference on the state-plane coordinate system marked a key step in advancing the theory of state-plane coordinate systems and map projections for large-scale mapping. By bringing together science, practice, and policy, the event strengthened the foundation for a modern national CRS that will benefit geospatial applications, environmental monitoring, surveying, topographic mapping, cadastre, civil engineering, GIS, and all national-level activities related to geospatial data and information. For practitioners and researchers, this development offers a timely opportunity to align projects and data infrastructures with evolving national standards, enhance data interoperability, and strengthen the scientific quality of analyses.

Prepared by

Bashkim Idrizi, Chair, North Macedonia, and
Lyubka Pashova, Co-chair, Bulgaria

Scientific committee

Bashkim Idrizi (Chair, North Macedonia), Lyubka Pashova (Co-chair, Bulgaria), Georg Gartner (Austria), Temenoujka Bandrova (Bulgaria), Miljenko Lapaine (Croatia), Chryssy Potsiou (Greece), Bekim Fetaji (North Macedonia), Pal Nikolli (Albania), Fitore Bajrami Lubishtani (Kosovo), Ibrahim Öztuğ Bildirici (Türkiye), Danko Markovinovic (Croatia), Vlado Cetl (Croatia), Ismail Kabashi (Austria), Veton Hamza (Slovenia), Michael Gastner (Singapore), Sagi Dalyot (Israel), Hartmut Mueller (Germany), Slobodanka Kljucanin (Bosnia and Hercegovina), Fisnik Loshi (Kosovo), Subija Izeiroski (North Macedonia).

Related publications

https://www.facebook.com/share/p/1CTAcmAZ3V/

https://www.linkedin.com/feed/update/urn:li:activity:7391063689736466432/

https://www.facebook.com/share/p/1BAytVD2z8/

https://www.facebook.com/share/p/1CbFsqYpjH/

#GeoSEE #FIG #EGoS #GeoSensors #комoранапред #BCA #CSC #KAS #FARO #Conference #SCRS #Geodesy #MapProjections #Cartography #StateCoordinateSystem #GIS #SpatialData #NorthMacedonia #GeospatialScience #ETRS89

Acknowledgements

The GeoSEE is grateful to the co-organizers, presenters and participants of the conference, as well as to the sponsors for their financial support, valuable input, and feedback.

DOI: 10.5281/zenodo.17703323

CONFERENCE PROGRAM *LINK4DOWNLOAD*

8:30-9:30	**Registration**	***Conference classroom B102*** – *LOCATION in Google Map*
9:30-11:00	Opening of conference & first session *Moderators:* Bashkim Idrizi, *North Macedonia* Chryssy Potsiou, *Greece* Nikola Ribaroski, *North Macedonia*	Official opening of conference *(9.30-9.40)* - Bekim Fetaji, Rector of the *"Mother Teresa" University – Skopje* Welcome speeches *(9.40-10):* - Diane Dumashie, President of the *International Federation of Surveyors - FIG* - Georg Gartner, President of the *International Cartographic Association - ICA* - Nikos Zacharias, President of the *European Group of Surveyors* - Subija Izeiroski, President of the *Geo-SEE Institute* - Nikola Ribaroski, President of the *Chamber of Surveyors* - Lyubka Pashova, *Vice chair of the conference* Presentation of General sponsor *(10-10.15*): - Geo Sensors, *Celestina Roshniku* - FARO, *Michaela Ragossnig* Scientific/professional presentations (10.15-11): 1. Standard parallels choice for Lambert conformal conic projection for Bulgaria - BGS2005 *Temenoujka Bandrova* 2. State Map Projection in Croatia *Miljenko Lapaine* 3. Coordinate Systems and Map Projections Used in Mapping and GIS Activities in Turkey *İbrahim Öztuğ Bildirici*
11:00-11.30	**Coffee break**	
11.30-13:00	Second session *Moderators:* Hrvoje Matijevic, *Croatia* Teuta Jusufi Zenku, *North Macedonia* Jochem Lesparre, *Netherlands*	1. Some key facts for the realization of a modern National Geodetic Reference System/Frame: The Hellenic case *Dimitrios Ampatzidis, Alexandros Konstantinidis, Konstantinos Papatheodorou* 2. Challenges and Harmonization of Local Datum Transformations within the Coordinate Reference Systems of North Macedonia *Zoran Cvetkovski, Nikola Ribaroski*

		3. UAV LiDAR and GNSS Surveys for High-Accuracy Spatial Data Acquisition Case Studies from Croatia and Bosnia and Herzegovina *Nikola Kranjčić, Vlado Cetl, Hrvoje Matijević, Danko Markovinović* 4. The role of coordinates in Border Diplomacy: The case of Albania *Anduel Cauli, Pal Nikolli, Oltion Pupi* 5. Geodetic Reference Systems and Map Projections in Bulgaria: Historical Context and Modern Applications *Lyubka Pashova*
13:00-13.45	**Lunch break**	
13.45-15:00	Third session *Moderators:* Celestina Roshniku, Albania Subija Izeiroski, North Macedonia Lyubka Pashova, Bulgaria	1. From EPSG 2462 to EPSG 6870: The evolution of coordinate systems in Albania *Pal Nikolli, Sonila Sinjari, Xhulia Bygjymi, Denisa Kukajc* 2. Making a new CRS inside Europe: practical considerations *Javier Jimenez Shaw* 3. Assessment of the Kosova National Coordinate System (KOSOVAREF01) and Evaluation of Alternative Options *Fitore Bajrami Lubishtani, Milot Lubishtani, Pal Nikolli, Bashkim Idrizi* 4. Modernised transformation between the Dutch century-old national CRS and ETRS89 *Jochem Lesparre, Lennard Huisman* 5. State plane coordinate systems of North Macedonia *Bashkim Idrizi*
15:00-15.30	Closing session *Moderators:* Nikos Zacharias, Greece Vlado Cetl, Croatia Murat Hoxha, Kosovo	Panel discussion: Temenoujka Bandrova, *President of the Bulgarian Cartographic Association* Javier Jimenez Shaw, *Member of the Project Steering Committee of PROJ* İbrahim Öztuğ Bildirici, *Expert on map projections* Bashkim Idrizi, *Head of project and TSPCS conference chair.*

INTERNATIONAL CONFERENCE

"Towards a State Plane Coordinate System: Scientific Approaches and Practical Challenges"

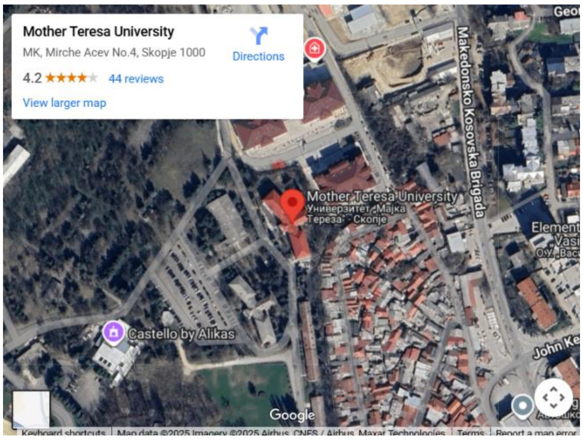
https://www.scrsproject.mk/p/international-conference.html *Skopje – October 31, 2025*

SCIENTIFIC COMMITTEE: Bashkim Idrizi *(Chair, North Macedonia)*, Lyubka Pashova *(Co-chair, Bulgaria)*, Georg Gartner *(Austria)*, Temenoujka Bandrova *(Bulgaria)*, Miljenko Lapaine *(Croatia)*, Chryssy Potsiou *(Greece)*, Bekim Fetaji (*North Macedonia*), Pal Nikolli *(Albania)*, Fitore Bajrami Lubishtani *(Kosovo)*, Ibrahim Oztug Bildirici *(Türkiye)*, Danko Markovinovic *(Croatia)*, Vlado Cetl *(Croatia)*, Ismail Kabashi *(Austria)*, Veton Hamza *(Slovenia)*, Michael Gastner *(Singapore)*, Sagi Dalyot (*Israel*), Hartmut Mueller *(Germany)*, Slobodanka Kljucanin *(Bosnia and Hercegovina)*, Fisnik Loshi *(Kosovo)*, Subija Izeiroski *(North Macedonia)*

ORGANIZER: South-East European Research Institute on Geo Sciences

UNDER THE UMBRELLA OF: International Federation of Surveyors

VENUE/HOST: University "Mother Teresa" - Skopje



CO-ORGANIZERS:

- Bulgarian Cartographic Association
- Croatian Cartographic Society
- Kosovo Association of Surveyors
- European Group of Surveyors
- University "Mother Teresa" - Skopje
- Macedonian Chamber of Trade Surveying Companies

SPONSORS:

- Geo Sensors
- FARO

INTERNATIONAL SCIENTIFIC CONFERENCE

TOWARDS A STATE PLANE COORDINATE SYSTEM

SCIENTIFIC APPROACHES AND PRACTICAL CHALLENGES

OCTOBER 31, 2025 - FRIDAY
VENUE: Hybrid form of conference
→ In Skopje with physical attendance,
→ Online for international participants

http://www.scrsproject.mk/p/international-conference.html