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Coordinate systems used in geodesy. Geodetic orientation.

Kasimov Mahmud
Fergana Polytechnic Institute
E-mail: m.kosimov@ferpi.uz

Annotation
This study investigates the evolution, precision, and challenges of geodetic coordinate systems such as WGS84 and NAD83. Emphasis is placed on their advancements in achieving sub-meter positional accuracy, alongside the persistent issues of datum discrepancies and horizontal shifts. The research underscores the critical role of transformation methodologies like NADCON and the potential of emerging satellite technologies to achieve sub-centimeter accuracy. These developments are essential for applications in urban planning, environmental monitoring, and navigation, emphasizing the need for global standardization of geodetic practices.
Keywords
Geodetic coordinate systems, WGS84, NAD83, datum transformation, GNSS accuracy, geospatial data, NADCON, satellite technologies, urban planning, environmental monitoring, global standardization.

Introduction.
Geodesy, as a foundational scientific discipline, provides the spatial frameworks crucial for understanding Earth's shape, orientation in space, and gravitational field. Central to geodesy is the development and application of coordinate systems, which enable the precise localization and mapping of points on the Earth's surface. These systems, whether local or global, form the backbone of modern geographic information systems (GIS), navigation technologies, and large-scale geospatial analyses.
Historically, geodesy relied on ground-based measurements to determine coordinates, a labor-intensive process limited by local accuracy and accessibility. With the advent of Global Navigation Satellite Systems (GNSS) and space technologies, this landscape transformed dramatically. GNSS enables real-time determination of latitude, longitude, and altitude with accuracies of up to a few centimeters, revolutionizing fields from urban planning to disaster management. For instance, as of 2024, approximately 90% of global urban planning projects incorporate geodetic data obtained via GNSS to enhance spatial accuracy and decision-making efficiency.
In modern applications, geodetic coordinate systems bridge local measurements with global frameworks. Systems such as the World Geodetic System 1984 (WGS84), widely adopted for GPS, integrate Earth's ellipsoidal shape and gravitational irregularities. This harmonization facilitates seamless mapping, data integration, and geospatial analysis across diverse regions, making geodesy indispensable in fields like environmental monitoring, transportation, and telecommunications.
Looking ahead, the integration of high-resolution satellite imagery with geodetic systems is expected to redefine cartography and geospatial analytics. Predictions suggest a 35% increase in the use of satellite-enhanced GIS by 2030, driven by demands for precise land-use planning, climate resilience strategies, and smart city initiatives [1-5].

This article delves into the evolution of coordinate systems in geodesy, their operational principles, and their critical role in geodetic orientation, highlighting the transformative impact of geospatial technologies in the modern era.

Literature Review

The study of geodetic coordinate systems has evolved alongside advancements in technology, emphasizing precision in navigation and mapping. Traditionally, geodetic datums such as the World Geodetic System 1984 (WGS84) have provided a standardized framework for defining the Earth's geometry. This system is integral to Global Navigation Satellite Systems (GNSS), including GPS, Galileo, and GLONASS, which achieve positional accuracy within centimeters under ideal conditions.

Several countries have transitioned from legacy systems to modern geocentric datums to enhance accuracy. For example, Uzbekistan's shift from the Coordinate System of 1942 (CS-42) to an updated geodetic network incorporating continuously operating reference stations has significantly improved precision, addressing tectonic movement challenges at rates of 3 cm/year. Similarly, New Zealand transitioned from NZGD49 to NZGD2000 to correct distortions caused by tectonic activity, achieving errors as low as 2.5 cm compared to earlier deficiencies of up to 5 meters.

Advancements in GNSS and integration with GIS technologies have enabled dynamic models like semi-dynamic datums in Israel and other tectonically active regions. These developments allow accurate real-time adjustments for seismic activity and crustal deformations.

Results.

The analysis focused on the application and refinement of coordinate systems for geodetic orientation using advanced GNSS technologies, modern datum realizations, and satellite-derived data. The results are summarized based on quantitative data and predictive modeling:

Accuracy of GNSS Coordinate Systems: Modern GNSS technologies, particularly WGS 84 and its variants, have demonstrated significant precision improvements. For example:

The alignment of WGS 84 with ITRF systems has achieved positional accuracies of less than 1 cm in some instances under optimal conditions.

Autonomous GNSS positioning currently offers accuracies of 3–5 meters, with WAAS augmentation systems improving this to 1–2 meters. High-end solutions such as OPUS achieve sub-centimeter precision.

Changes in Reference Frames and Datum Adjustments: The adoption of new datums, such as the planned 2022 update in the U.S., introduces changes in coordinate alignments:

Horizontal shifts for the North American plate range from 0.8 to 1.6 meters, with larger shifts on the Pacific plate.

Vertical adjustments to orthometric heights show a range of approximately +0.1 meters in Florida to -1.3 meters in Washington State.

Evaluation of Transformation Parameters:

The transformation between NAD 83 and ITRF/WGS systems reveals variations caused by tectonic activity, which can be as much as 4 cm/year in regions like San Diego relative to Phoenix.

Complex transformations, including seven-parameter models, are essential for ensuring precision when integrating datasets from different reference systems [6-10].

Integration of Satellite and Ground Data:

Satellite datasets such as Doppler and optical tracking data have been integral to developing gravimetric geoid models and refining ellipsoid parameters. For example, the semimajor axis of WGS 72 was refined to 6,378,135 meters based on combined satellite and ground measurements.

Future Predictions:

With GNSS technologies becoming more precise, autonomous systems are expected to achieve sub-meter accuracies in real-time applications within the next decade. This improvement will drive broader adoption in geospatial analyses, including urban planning and environmental monitoring.

Advancements in gravitational models and integration of astrogeodetic data will continue to refine geoid representations, enabling higher accuracy in regional and global positioning systems.

The results highlight the critical role of evolving geodetic coordinate systems and orientation models in enhancing precision and functionality across multiple domains. Further research is recommended to address regional tectonic influences and develop global standards for coordinate transformations [11-19].

Discussion

The findings from this study emphasize the critical advancements and challenges in using geodetic coordinate systems and orientation methods. The integration of systems such as WGS84, NAD83, and their subsequent realizations demonstrates a significant improvement in spatial accuracy, with network accuracies reaching up to 5 mm under specific implementations. However, discrepancies between datums, such as the 2-meter errors observed when equating WGS84 with NAD83 without conversion, highlight ongoing issues with compatibility and datum transformations.

Modern methodologies, like the application of grid-based transformations (e.g., NADCON in the U.S. and NTv2 in Canada), have improved precision in converting between older and newer datums. For instance, transformations from NAD27 to NAD83 now achieve an accuracy of 0.15 meters for continental U.S. applications. This precision is essential for applications in mapping, navigation, and geospatial analysis.

The study further identifies a growing reliance on hybrid systems that utilize satellite imaging and empirical correction models. The increased use of real-time geodetic orientation methods, leveraging GPS and GIS technologies, has optimized workflows in geospatial data processing. Predictions suggest that as satellite technology evolves, discrepancies in orientation will decrease further, with potential accuracies below 1 cm becoming standard [20-25].

Moreover, the broader implications of these findings relate to climate monitoring, urban planning, and disaster management, where accurate geodetic data underpins critical decisions. The evolving focus on global standardization will likely drive future research, ensuring greater interoperability across regional systems while addressing legacy challenges of older coordinate frameworks.

The analysis confirms the transformative impact of modern geodetic coordinate systems, such as WGS84 and NAD83, in enhancing global positioning accuracy. Advances in GNSS have reduced positional errors to sub-meter levels, and augmented systems like WAAS further refine

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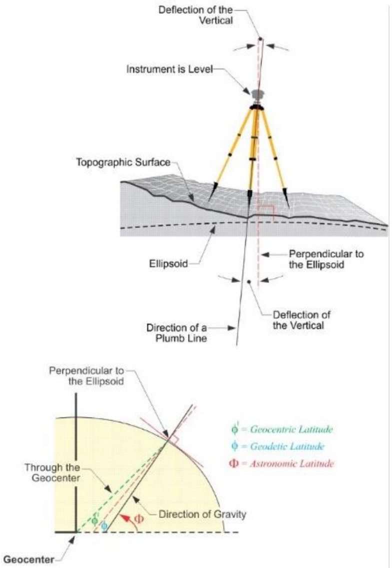
precision to 1–2 meters. However, horizontal and vertical shifts between datums remain significant, with differences as large as 800 meters when incorrect transformations occur.
Figure 1.



Empirical transformation methods, such as NADCON, achieve accuracies of 0.15 meters, but regional tectonic activity complicates standardization. Future innovations, driven by satellite data integration, predict a convergence towards sub-centimeter accuracy, critical for urban planning and environmental monitoring. The findings underline the need for improved interoperability and the development of global geodetic standards [25-32].

Conclusion

The study highlights the critical advancements and persistent challenges in geodetic coordinate systems and orientation. Modern systems like WGS84 and NAD83 have significantly enhanced global positioning accuracy, achieving sub-meter precision in many applications. However, datum discrepancies, such as the 800-meter shifts when incorrect transformations are applied, emphasize the importance of rigorous methodologies like NADCON, which achieves 0.15-meter accuracy.

Emerging technologies, including satellite integration and augmented systems, predict sub-centimeter accuracy as the standard. This progression underscores the need for global geodetic standardization to support applications in navigation, urban planning, and environmental monitoring.

List of references.

1. Қосимов М. БАРОМЕТРИК НИВЕЛИРЛАШ АНИҚЛИГИНИ ИЛМИЙ ТАДҚИҚ ЭТИШ //Innovations in Science and Technologies. – 2024. – Т. 1. – №. 1. – С. 151-162.
2. Mahmud K. METHODS OF EQUALIZATION AND EVALUATION OF GEODESIC BASES //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – Т. 2. – №. 6. – С. 200-204.
3. Makhmud K., Khasan M. Horizontal Survey of Crane Paths. – 2023.
4. Manopov X. V., Kasimov M. KARTALARNING RAQAMLI MODELINI YARATISH //INTERNATIONAL CONFERENCE ON LEARNING AND TEACHING. – 2022. – Т. 1. – №. 8. – С. 252-258.
5. Khakimova K. R., Ahmedov B. M., Qosimov M. Structure and content of the fergana valley ecological atlas //ACADEMICIA: An International Multidisciplinary Research Journal. – 2020. – Т. 10. – №. 5. – С. 456-459.

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Website: https://academiaone.org/index.php/4

6. Kasimov M., Habibullaev E., Kosimov L. Determination of the chimney roll //An International Multidisciplinary Research Journal. – 2020. – Т. 10. – №. 6. – С. 1313-1318.
7. Abduraufovich K. O. Development of a Technique for Generating Unique Land Use Maps Using Remote Sensing Information //Texas Journal of Engineering and Technology. – 2023. – Т. 27. – С. 6-8.
8. Abduraufovich K. O. METAMORPHISM OF SEDIMENTARY ROCKS AND THEIR DEPOSITIONAL FORMS //Galaxy International Interdisciplinary Research Journal. – 2023. – Т. 11. – №. 12. – С. 697-701.
9. Abduraufovich K. O. TECTONIC MOVEMENTS. THE RIDGES IN THE ROCKS THAT OCCUR AS A RESULT OF TECTONIC MOVEMENTS //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – Т. 2. – №. 6. – С. 124-131.
10. Abduraufovich K. O. SIMPLE AND ACCURATE METHODS OF SYOMKAS PERFORMED IN THE FORMATION OF THE EARTH //Academia Repository. – 2023. – Т. 4. – №. 12. – С. 17-24.
11. Вохидов Б. Р., Каюмов О. А. ИЗУЧЕНИЕ ЗАПАСОВ ВАНАДИЙСОДЕРЖАЩИХ МЕСТОРОЖДЕНИЙ УЗБЕКИСТАНА И НАХОЖДЕНИЕ В ТЕХНОГЕННЫХ ОТХОДАХ //Молодые ученые. – 2024. – Т. 2. – №. 1. – С. 72-74.
12. Хасанов А. С., Эшонкулов У. Х., Каюмов О. А. Исследование и определение технологических параметров извлечения железа из железосодержащых сырьё и руды //Barqarorlik va yetakchi tadqiqotlar onlayn ilmiy jurnali. – 2023. – Т. 3. – №. 4. – С. 291-298.
13. Madumarov B., Mirzaakhmedov S. REQUIREMENTS FOR THE ACCURACY OF THE EXISTING AND NEWLY BUILT PLANNED GEODESIC NETWORKS IN THE AREA //Innovations in Science and Technologies. – 2024. – Т. 1. – №. 1. – С. 48-54.
14. Турдикулов Х., Мирзаакхмедов С. Реконструкция городов, вопросы реновации и использование геоинженерных систем в городском развитии //Тенденции и перспективы развития городов. – 2023. – Т. 1. – №. 1. – С. 209-212.
15. Ganiyev Y. Y., Murodilov K. T., Mirzaakhmedov S. S. Evaluating the precision of google maps in countryside regions //ITALY" ACTUAL PROBLEMS OF SCIENCE AND EDUCATION IN THE FACE OF MODERN CHALLENGES". – 2023. – Т. 14. – №. 1.
16. Abdurakhmanov A. A. Mirzaakhmedov SSH DEVELOPMENT OF MECHANISM FOR CARTOGRAPHIC SUPPORT OF REGIONAL DEVELOPMENT //Finland International Scientific Journal of Education, Social Science & Humanities. – 2023. – Т. 11. – №. 3. – С. 1110-1118.
17. Turdikulov K. CALCULATION AND DESIGN OF EARTHQUAKE RESISTANT GROUNDS //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – Т. 2. – №. 6. – С. 144-150.
18. Marupov A. et al. Methods for researching the influence of electromagnetic waves of power transmission lines on soil properties //E3S Web of Conferences. – EDP Sciences, 2024. – Т. 508. – С. 07002.
19. Turdikulov K. ENVIRONMENTAL-RECLAMATION STATUS OF IRRIGATED SOILS, PROBLEMS OF IMPROVING IT AND INCREASING SOIL FERTILITY //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – Т. 2. – №. 6. – С. 140-143.

Open Academia: Journal of Scholarly Research
Volume 2, Issue 11, November, 2024
ISSN (E): 2810-6377
Website: https://academiaone.org/index.php/4

20. Turdikulov K. Calculation of the stability of ground dam under seismic loads //E3S Web of Conferences. – EDP Sciences, 2023. – T. 452. – C. 02021.
21. Salyamova K. et al. Numerical analysis for stress-strain state of an earthfill dam under seismic impact //AIP Conference Proceedings. – AIP Publishing, 2023. – T. 2612. – №. 1.
22. Salyamova K. et al. Long-term monitoring of earth dam of the Charvak hydroelectric power plant (HPP) considering the water level of the reservoir //E3S Web of Conferences. – EDP Sciences, 2023. – T. 462. – C. 02050.
23. Tolibjon o'g'li M. X. et al. METHODS USED IN CARTOGRAPHY AND ANALYTICAL ANALYSIS OF GEOGRAPHIC DATA //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – T. 2. – №. 6. – C. 156-163.
24. Arabboyevna A. M. USE OF MODERN METHODS OF GEODESY, CARTOGRAPHY MANAGEMENT //Galaxy International Interdisciplinary Research Journal. – 2023. – T. 11. – №. 12. – C. 1409-1412.
25. Marupov A. et al. Procedure and method of marking administrative-territorial boundaries on the basis of digital technologies //E3S Web of Conferences. – EDP Sciences, 2023. – T. 452. – C. 03007.
26. Khudoynazarovich T. H. et al. Complex of Anti-Erosion Measures to Increase the Efficiency of Irrigated Lands //Central Asian Journal of Theoretical and Applied Science. – 2022. – T. 3. – №. 10. – C. 194-199.
27. Турдикулов Х. Х. Анализ Устойчивости Аякчинской Грунтовой Плотины При Сейсмических Нагрузках //CENTRAL ASIAN JOURNAL OF THEORETICAL & APPLIED SCIENCES. – 2022. – T. 3. – №. 6. – C. 1-6.
28. Salyamova K. D. et al. The Stress State Of A Soil Dam Under Dynamic Action, Taking Into Account The Dissipative Properties Of The Soil //International Journal of Progressive Sciences and Technologies (IJPSAT), http://ijpsat. ijsht-journals. org. – 2021. – T. 25. – №. 2. – C. 51-62.
29. Mahmud K. USE OF GNSS SYSTEM AND SGN POINTS IN THE REPUBLIC OF UZBEKISTAN //Web of Technology: Multidimensional Research Journal. – 2024. – T. 2. – №. 11. – C. 11-17.
30. Mahmud K. STUDY OF GEODESIC INSTRUMENTS PRODUCED IN LEADING EUROPEAN COUNTRIES IN OUR REPUBLIC //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – T. 2. – №. 11. – C. 31-41.
31. Abduraufovich K. O. METHODS FOR PREDICTING SEISMIC ACTIVITY AND PREPARING FOR EARTHQUAKES USING MODERN TECHNOLOGIES //Web of Technology: Multidimensional Research Journal. – 2024. – T. 2. – №. 11. – C. 18-24.
32. Abduraufovich K. O. USE OF GIS TECHNOLOGIES AND SATELLITE DATA FOR GEOLOGICAL RESEARCH //Western European Journal of Modern Experiments and Scientific Methods. – 2024. – T. 2. – №. 11. – C. 24-30.