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Global Assessment of Qibla Orientation in Mosques Using Satellite Imagery: A Geospatial and Islamic Astronomy Approach

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ABSTRACT

This study analyzes the accuracy of mosque building orientations relative to the actual Qibla direction in various regions of the world using Google Earth technology through geospatial and Islamic astronomy approaches. Using quantitative-descriptive methods, this study involved four representative mosques from the four cardinal directions to the Kaaba: the Blue Mosque in Turkey, the Jama Mosque in India, the Istiqlal Mosque in Kenya, and the Al-Azhar Mosque in Egypt. Data were collected through geographic coordinates, building orientation measurements, theoretical Qibla direction calculations using the great circle bearing formula, and deviation analysis based on satellite imagery. The results show that the Qibla direction deviation varies between 0.1° and 4.7°, with an average of less than 3°, indicating a very high level of accuracy. Mosques in regions closer to Mecca, such as Turkey and Egypt, show minimal deviations, while mosques in India and Kenya have slightly larger deviations due to the influence of traditional methods and local architectural factors. The research conclusion confirms that the integration of geospatial and astronomical methods is effective in validating the direction of the Qibla globally and has the potential to support the development of digital mapping systems and the calibration of the Qibla direction in historic mosques in various countries.

ARTICLE INFO

ABSTRACT

Penelitian ini bertujuan menganalisis tingkat akurasi orientasi bangunan masjid terhadap arah kiblat sejati di berbagai wilayah dunia dengan memanfaatkan teknologi Google Earth melalui pendekatan geospasial dan astronomi Islam. Menggunakan metode kuantitatif-deskriptif, penelitian ini melibatkan empat masjid representatif dari empat arah mata angin terhadap Ka'bah, yaitu Masjid Biru di Turki, Jama Masjid di India, Masjid Istiqlal di Kenya, dan Masjid Al-Azhar di Mesir. Data dikumpulkan melalui koordinat geografis, pengukuran orientasi bangunan, perhitungan arah kiblat teoritis dengan rumus great circle bearing, serta analisis deviasi berdasarkan citra satelit. Hasil penelitian menunjukkan bahwa deviasi arah kiblat bervariasi antara 0,1° hingga 4,7°, dengan rata-rata di bawah 3°, menandakan tingkat akurasi yang sangat tinggi. Masjid di wilayah yang lebih dekat dengan Makkah, seperti Turki dan Mesir, menunjukkan deviasi minimal, sedangkan di India dan Kenya deviasi sedikit lebih besar akibat pengaruh metode tradisional dan faktor arsitektural lokal. Kesimpulan penelitian menegaskan bahwa integrasi metode geospasial dan falakiyah efektif untuk validasi arah kiblat secara global serta berpotensi mendukung pengembangan sistem pemetaan digital dan kalibrasi arah kiblat masjid-masjid bersejarah di berbagai negara.

INTRODUCTION

Determining the direction of the Qibla is a fundamental requirement in Islamic worship, particularly in the performance of salat (ritual prayer), which requires Muslims to face the Kaaba located inside the Grand Mosque in Mecca. Consequently, accurate determination of the Qibla direction has attracted continuous academic attention since the early Islamic period and has developed into an interdisciplinary field of study encompassing astronomy, geodesy, mathematics, and architecture. Throughout history, various traditional methods have been developed to determine the direction of the Qibla, including observations of the sun, the Pole Star (Qutb or Kutub al-Shamālī), and the use of a magnetic compass. While these methods have contributed significantly to the advancement of

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the science of Qibla, their accuracy varies depending on the observation conditions, instrument precision, and geographic context. Furthermore, limitations in measurement techniques and the influence of magnetic declination often result in differences in the Qibla orientation of mosques in different regions of the world.[1]

Today, geospatial technology and Geographic Information Systems (GIS) have transformed the way Qibla orientation is determined, enabling more scientific, accurate, and efficient measurements. In this regard, Google Earth Pro has become a valuable tool for measuring geographic coordinates, analyzing building orientations, and evaluating Qibla direction based on the World Geodetic System 1984 (WGS 84) and high-resolution satellite imagery. In addition to its time and cost efficiency, this approach provides intuitive spatial visualization that facilitates verification of mosque alignment with the true Qibla direction. Consequently, the integration of GIS and satellite-based geospatial technologies has significantly improved the accuracy, reliability, and accessibility of Qibla studies, offering a robust framework for assessing mosque Qibla orientation across diverse geographic regions.

Previous studies in Islamic astronomy suggest that the accuracy of Qibla orientation is shaped by a complex interplay of geographical, historical, and methodological factors. In general, mosques located closer to Makkah tend to exhibit smaller deviations from the true Qibla direction, reflecting the enduring influence of classical Islamic astronomical traditions and architectural practices centered on the Kaʿbah.[2] By contrast, mosques situated in more distant regions often display greater variations in orientation, partly due to the continued reliance on

[1]Siti Tatmainul Qulub, *Ilmu Falak : Dari Sejarah Ke Teori Dan Aplikasi* (Depok: PT RAJAGRAFINDO PERSADA, 2017).

[2]Fachrudin Ad'han Tohari, "Pendidikan Islam Holistik: Eksistensi Masjid Sebagai Pusat Peradaban Islam Pada Masyarakat Modern," *Proceeding of International Conference on Islamic Education (ICIED)* 10, no. 1 (December 31, 2025): 1024, https://doi.org/10.18860/icied.v10i1.3723.

traditional methods that do not incorporate geodetic corrections or modern geospatial techniques. Against this backdrop, the validation of Qibla orientation using geospatial approaches has become increasingly important, serving not only as a means of advancing scientific inquiry but also as a way to ensure the accuracy of religious practice and reinforce public confidence in mosque orientations.[3]

Building upon these considerations, this study investigates the accuracy of mosque orientations relative to the true Qibla direction across diverse regions of the world by integrating geospatial analysis with Islamic astronomy using Google Earth.[4] Four representative mosques, located in different cardinal directions with respect to the Kaʿbah and situated in distinct geographical contexts, were selected as case studies: the Blue Mosque in Turkey, Jama Masjid in India, Istiqlal Mosque in Kenya, and Al-Azhar Mosque in Egypt. By comparing these cases, the study seeks to reveal global patterns of Qibla deviation and to assess the influence of geographical factors on mosque orientation.[5] Ultimately, the findings are expected to advance the development of digital Qibla mapping systems and provide a robust scientific basis for validating the orientations of historical mosques through satellite imagery and geospatial techniques.

METHOD

This study adopted a quantitative descriptive research design to investigate the deviation of mosque orientations from the true Qibla direction using high-resolution satellite imagery provided by Google Earth Pro.

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[3]Muhammad Syakir Maula, "Integrasi Pengetahuan Arah Kiblat Dalam Pendidikan Islam: Kerangka Pedagogis Untuk Meningkatkan Pemahaman Keagamaan," *An-Nida: Jurnal Pendidikan Islam* 13, no. 1 (October 20, 2024): 1–16, https://doi.org/10.30999/an-nida.v13i1.3418.

[4]Nur Qalbi Indrayani Qalbi and Irfan Irfan, "Akurasi Arah Kiblat Masjid Di Desa Batumalonro Kecamatan Biringbulu Kabupaten Gowa Perspektif Ilmu Falak," *HISABUNA: Jurnal Ilmu Falak* 2, no. 3 (November 26, 2021): 33–48, https://doi.org/10.24252/hisabuna.v2i3.17166.

[5]Muhammad Rais, "Masjid Agung Paris Di Jantung Kiblat Mode Dunia," *PUSAKA* 4, no. 2 (November 23, 2016): 126–45, https://doi.org/10.31969/PUSAKA.V4I2.159.

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The study integrates two complementary scientific disciplines, namely geospatial science and Islamic astronomy (*ʿilm al-falak*). Geospatial techniques were employed to measure and map the orientation of mosque buildings, whereas Islamic astronomy provided the theoretical and computational basis for determining the true Qibla direction with a high degree of precision.[6] The methodological procedure consisted of several sequential stages. First, primary data were collected in the form of geographical coordinates and the orientations of the principal axes of mosque buildings. Second, the theoretical Qibla direction was calculated using secondary data, including relevant scholarly literature and the global geodetic reference framework of the World Geodetic System 1984 (WGS 84). Third, deviations between the observed mosque orientations and the theoretical Qibla directions were quantified and analyzed. Finally, the results were visualized and interpreted using geospatial mapping techniques to facilitate a comprehensive assessment of mosque orientation accuracy across different geographical contexts.[7]

To investigate variations in Qibla orientation accuracy across different historical and geographical contexts, this study selected four case studies from regions situated in the cardinal directions relative to the Kaʿbah: Turkey (north), India (east), Kenya (south), and Egypt (west).[8] A purposive sampling strategy was employed to identify one

[6]Muhammad Thoyfur, "Perkembangan Metode Dan Instrumen Arah Kiblat Abad Pertengahan: Studi Kajian Historis Perspektif David a King," *AL - AFAQ : Jurnal Ilmu Falak Dan Astronomi* 3, no. 1 (July 19, 2021): 41–58, https://doi.org/10.20414/afaq.v3i1.2879.

[7]Muhammad Thoyfur, "Digitalization Of Local Rashdul Qibla By Qibla Diagram," *Al-Hilal: Journal of Islamic Astronomy* 3, no. 1 (2021), https://doi.org/10.21580/al-hilal.2021.3.1.7697.

[8]Anisah Budiwati, "Akurasi Arah Kiblat Masjid Di Ruang Publik," *JSSH (Jurnal Sains Sosial Dan Humaniora)* 2, no. 1 (March 28, 2018): 159, https://doi.org/10.30595/jssh.v2i1.2275.

representative mosque from each region. The selection process was guided by several criteria, including the mosque's historical and architectural significance, the availability of high-resolution satellite imagery with a spatial resolution of at least 1 m, the clarity of the building's orientation, and the accessibility of accurate geospatial information referenced to the precise geographical coordinates of the Kaʿbah (21°25′21.2″ LU, 39°49′34.1″ BT. These criteria ensured that the selected case studies provided a robust basis for evaluating mosque orientation accuracy and for examining regional variations in Qibla deviations.[9]

RESULTS AND DISCUSSIONS

The results indicate that the accuracy of mosque orientations toward the true Qibla direction varies across different countries, although the overall level of accuracy is remarkably high. Based on measurements derived from Google Earth Pro satellite imagery and theoretical Qibla calculations using the spherical trigonometry approach, specifically the Great Circle Bearing formula, the mosques in Turkey and Egypt exhibited highly accurate orientations, with deviations of less than one degree, measuring 0.5° and 0.1°, respectively. In contrast, the mosques in India and Kenya showed slightly larger deviations of 4.7° and 3.2°, respectively; nevertheless, these values remain within an acceptable range of accuracy for Qibla orientation.[10] These findings indicate that most modern mosques are oriented toward the Qibla with a high

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[9]Anisah Budiwati, Muhammad Wahyu Firdaus, and Galih Cipto Raharjo, "Integration Method for Measuring Qibla Direction (Comparative Analysis of Google Earth and Mizwala)," *Indonesian Journal of Interdisciplinary Islamic Studies* 5, no. 3 (December 30, 2022), https://doi.org/10.20885/IJIIS.VOL.5.ISS3.ART2.

[10]Rahman Helmi and H. Badrian, "Akurasi Arah Kiblat Masjid-Masjid Di Kabupaten Banjar," *Indonesian Journal of Islamic Jurisprudence, Economic and Legal Theory* 2, no. 1 (February 10, 2024): 215–27, https://doi.org/10.62976/ijijel.v2i1.439.

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degree of precision, reflecting the significant contributions of advances in geospatial technologies and Geographic Information Systems (GIS) to Qibla determination. As summarized in Table 1, the four mosques examined in this study exhibit varying degrees of deviation from the theoretical Qibla direction, highlighting regional differences in orientation accuracy while maintaining an overall high level of conformity with the true Qibla.

Table 1. Qibla Orientation Accuracy of Mosques in Four Countries:

No	Country	Mosque Coordinates (Lat., Long.)	Theoretical Qibla Direction (°)	Measured Mosque Orientation (°)	Deviation (°)	Description
1	Turkey	41.0054°N, 28.9768° E	151.0	150.5	0.5	Highly Accurate
2	India	28.6560°N, 77.2270° E	266.8	271.5	4.7	Moderately Accurate
3	Kenya	-1.2864°S, 36.8172°E	23.8	27.0	3.2	Moderately Accurate
4	Egypt	30.0444° N ,31.2357° E	136.1	136.0	0.1	Highly Accurate

Overall, the findings demonstrate that the integration of satellite imagery and Islamic astronomical methods provides an effective and reliable framework for validating Qibla orientations across different countries. In particular, the use of Google Earth and QGIS enables the determination of Qibla directions with a high degree of precision without requiring extensive field surveys, thereby offering significant advantages in terms of time

and cost efficiency.[11] Furthermore, this study underscores the importance of incorporating geospatial approaches into the planning and construction of modern mosques to ensure that their orientations are accurately aligned with the position of the Kaʿbah. Beyond its practical implications, the present research highlights the potential for developing a global digital Qibla mapping system that could serve as a valuable resource for religious institutions, governmental agencies, and the academic community in verifying and maintaining the accuracy of mosque orientations worldwide.[12]

The spatial visualization provided by Google Earth satellite imagery complements and strengthens the numerical findings of this study. By superimposing two azimuth lines "a red line representing the observed orientation of the mosque and a yellow line indicating the theoretical Qibla direction calculated from the geographical coordinates of the Kaʿbah" the analysis offers an intuitive and precise depiction of orientation deviations at each study site.[13] The four case studies, representing the cardinal directions relative to the Kaʿbah, exhibit only minor discrepancies between the observed and theoretical orientations. However, a gradual increase in deviation can be observed in mosques located farther from Makkah, indicating that geographical distance may play a role,

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[11]Safna Farah Dila, "A Comparative Analysis of Qibla Direction Accuracy Using a Theodolite, Mizwala, and Right-Angle Triangle at As-Sakinah Mosque, Surabaya," *Astroislamica: Journal of Islamic Astronomy* 4, no. 2 (December 31, 2025): 395–412, https://doi.org/10.47766/astroislamica.v4i2.4796.

[12]Nur Afny Awwalany, Sippah Chotban, and Subhan Khalik, "Peluang Dan Tantangan Ilmu Falak Di Indonesia Era Digital," *HISABUNA: Jurnal Ilmu Falak* 4, no. 3 (December 18, 2023): 123–46, https://doi.org/10.24252/HISABUNA.V4I3.40475.

[13]Abdulloh Hasan et al., "Digital Ijtihad in Determining the Direction of Qibla: Analysis of Accuracy and Limitations of Augmented Reality-Based Applications," *Syarah: Jurnal Hukum Islam Dan Ekonomi* 14, no. 2 (December 31, 2025): 150–67, https://doi.org/10.47766/SYARAH.V14I2.6755.

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alongside historical and methodological considerations, in shaping the accuracy of Qibla orientation.

Al-Azhar Mosque Cairo, Egypt

Figure 1. Al-Azhar Mosque, Cairo

As illustrated in Figure 1, Al-Azhar Mosque in Cairo, Egypt, exhibits a remarkable degree of alignment between the observed mosque orientation and the theoretical Qibla direction. The visualization shows that the red and yellow azimuth lines are nearly coincident, with an angular difference of only approximately 0.1°. This minimal deviation indicates that the mosque is oriented almost perfectly toward the true Qibla. Such a high level of accuracy may be attributed to historical and intellectual factors, given Egypt's long-standing role as a center of classical Islamic astronomy (ʿilm al-falak). The extensive knowledge of astronomical orientation possessed by Muslim scholars and architects in the past likely contributed to the exceptional precision observed in the Qibla orientations of many historical mosques in Egypt.[14]

The remarkable accuracy of Qibla orientation observed at Al-Azhar Mosque is deeply rooted in the historical and intellectual legacy of Islamic science in

[14]Rais, "Masjid Agung Paris Di Jantung Kiblat Mode Dunia."

Egypt. Established in the tenth century, Al-Azhar has long been recognized as one of the leading centers of scholarship in the Islamic world, contributing significantly to the development of Islamic astronomy (ʿilm al-falak) and related geodetic sciences that underpin Qibla determination. Scholars and architects of the medieval period employed sophisticated astronomical observations, including the positions of the Sun and the Pole Star (*Qutb* or *Kutub al-Shamālī*), to achieve precise alignments between mosque structures and the Kaʿbah.[15] The findings of the present study further support the view that the scientific traditions cultivated within classical Islamic astronomy fostered a remarkable level of architectural precision, enabling the construction of mosques with highly accurate Qibla orientations centuries before the emergence of modern coordinate systems and satellite-based geospatial technologies.[16]

Beyond its historical significance, the remarkable accuracy of Qibla orientation at Al-Azhar Mosque also reflects the effectiveness of integrating geospatial techniques with Islamic astronomy in contemporary analyses. Using latitude–longitude coordinates referenced to the WGS 84 geodetic framework, the theoretical Qibla direction was calculated through the Great Circle Bearing method, yielding an almost perfect agreement with the mosque's observed orientation derived from satellite imagery.[17] This close correspondence is further illustrated through geospatial visualization in Google Earth Pro,

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[15]Abdul Ghoffar, "The Influence of the Kaaba According to History in the Qur'an and Hadith on Islamic Architecture," *Journal of Islamic Architecture* 8, no. 4 (December 26, 2025): 1142–57, https://doi.org/10.18860/jia.v8i4.25443.

[16]Ismail Ismail, Dikson T. Yasin, and Zulfiah, "Toleransi Pelencengan Arah Kiblat Di Indonesia Perspektif Ilmu Falak Dan Hukum Islam," *Al-Mizan* 17, no. 1 (June 30, 2021): 115–38, https://doi.org/10.30603/am.v17i1.2070.

[17]Anisa Budiwati, "Tongkat Istiwa', Global Positioning System (GPS) Dan Google Earth Untuk Menentukan Titik Koordinat Bumi Dan Aplikasinya Dalam Penentuan Arah Kiblat," *Al-Ahkam* 26, no. 1 (2016).

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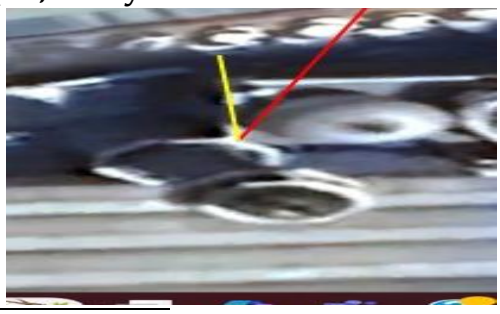
where the theoretical Qibla line (yellow) and the observed building orientation (red) converge at nearly identical azimuths. The convergence of these independent lines of evidence demonstrates the robustness of combining geospatial science and Islamic astronomy for the measurement and validation of Qibla orientations. More broadly, the findings highlight the potential of this interdisciplinary approach as a reliable framework for assessing the orientation accuracy of historical mosques across diverse geographical and cultural settings.[18]

Overall, the findings from Al-Azhar Mosque provide a compelling example of how the precision achieved by classical Islamic astronomers can be corroborated through modern geospatial technologies, resulting in an exceptionally accurate Qibla orientation. This case highlights the value of an interdisciplinary approach to the study of mosque orientation, in which religious, historical, and scientific dimensions converge to preserve the accuracy of Qibla alignment as one of the defining features of Islamic architecture. More broadly, it illustrates how the integration of traditional knowledge and contemporary scientific methods can contribute to a deeper understanding of the relationship between faith, science, and the built environment in the Islamic world.

Istiqlal Mosque, Kenya



[18]Machzumy Machzumy and Mahli Mahli, "Pendampingan Kalibrasi Arah Kiblat Bagi Imeum Chik Di Provinsi Aceh," *PengabdianMu: Jurnal Ilmiah Pengabdian Kepada Masyarakat* 9, no. 8 (August 12, 2024): 1374–84, https://doi.org/10.33084/pengabdianmu.v9i8.7090.

Figure 2. Istiqlal Mosque, Kenya

As shown in Figure 2, Istiqlal Mosque in Kenya, representing the East African region, exhibits a slight discrepancy between the observed mosque orientation (red line) and the theoretical Qibla direction (yellow line), with an angular deviation of approximately 3°. The mosque orientation is inclined marginally eastward relative to the true Qibla direction. This deviation may be attributed to several factors, including the use of traditional orientation methods during the early stages of construction, such as magnetic compass measurements without corrections for magnetic declination, as well as practical considerations related to the alignment of the building with the urban street network of Nairobi. Nevertheless, the observed deviation remains within the commonly accepted tolerance range for Qibla orientation (less than 5°), indicating that the mosque can still be regarded as reasonably accurate in its alignment toward the Kaʿbah.[19]

From a methodological perspective, these findings were derived from a quantitative descriptive approach based on geospatial data, integrating satellite imagery analysis with theoretical Qibla calculations using the Great Circle Bearing method. The adoption of the global geodetic reference system, WGS 84, together with Google Earth Pro, enabled the accurate determination of the mosque's geographical coordinates and the precise measurement of its observed orientation. The resulting deviation indicates a minor discrepancy between the physical orientation of the mosque and the astronomically calculated direction of the Kaʿbah.[20] This discrepancy underscores the importance

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[19]Ahmad Izzuddin, "Typology Jihatul Ka'bah on Qibla Direction of Mosques in Semarang," *Ulul Albab: Jurnal Studi Dan Penelitian Hukum Islam* 4, no. 1 (November 1, 2020): 1–15, https://doi.org/10.30659/JUA.V4I1.12186.

[20]Yusuf Nurqolbi DY, Ulil Albab Al aulia Alpaten, and Kurniawan Kurniawan, "Kajian Penentuan Arah Kiblat Dengan Sensor Magnetik Kompas Android," *Astroislamica: Journal of Islamic Astronomy* 3, no. 2

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of validating Qibla orientation through modern geospatial techniques. Traditional methods, such as magnetic compass measurements, often do not account for magnetic declination and other geographical corrections that are essential for achieving high-precision Qibla determination.[21]

From a historical and architectural perspective, the observed Qibla deviation at Istiqlal Mosque in Nairobi can be interpreted within the broader socio-technical context in which the mosque was constructed. Throughout much of East Africa, including Kenya, mosque architecture has often evolved in response to pre-existing urban morphologies and street networks, many of which were influenced by colonial planning frameworks organized along north–south or east–west axes. Consequently, the orientation of mosque buildings was not determined solely by religious considerations but was also shaped by practical constraints associated with urban design and the built environment. In such settings, local architects and builders may have relied on approximate methods for Qibla determination, including compass-based measurements or conventional directional estimates, in the absence of detailed astronomical observations and geodetic calculations. Moreover, the limited availability of precise surveying instruments, together with the spatial constraints imposed by dense urban environments, likely encouraged the alignment of mosque structures with major transportation corridors and surrounding architectural patterns. Viewed in this context, the Qibla deviation observed at Istiqlal Mosque should not be regarded as

(December 1, 2024): 193–210, https://doi.org/10.47766/astroislamica.v3i2.3429.

[21]Cut Nazar Mutia Hanum and Ismail Ismail, "Pandangan Tokoh Agama Jungka Gajah Terhadap Arah Kiblat Bagi Orang Yang Jauh Dari Ka'bah," *Astroislamica: Journal of Islamic Astronomy* 1, no. 2 (December 28, 2022): 169–86, https://doi.org/10.47766/ASTROISLAMICA.V1I2.934.

evidence of theological inconsistency or negligence. Rather, it reflects the complex interplay of geographical, historical, technological, and urban factors that have shaped mosque construction practices over time. This interpretation underscores the importance of contextualizing Qibla orientation studies within their historical and architectural settings, while also highlighting the value of modern geospatial methods in reassessing and validating the orientations of historical mosques with greater precision.[22]

Overall, the findings from Istiqlal Mosque demonstrate the effectiveness of integrating geospatial approaches with Islamic astronomy for the scientific identification and quantification of Qibla orientation deviations. The geospatial visualization employed in this study further illustrates how modern satellite technologies can be utilized to reassess and verify the orientations of long-established mosques without the need for extensive field measurements. Accordingly, the quantitative descriptive approach adopted in this research, grounded in spatial data analysis, not only strengthens the validation of Qibla orientation at Istiqlal Mosque but also offers a promising framework for the large-scale mapping and recalibration of Qibla directions across East Africa. This is particularly relevant for regions that share similar architectural traditions, historical backgrounds, and urban development patterns.

[22]Arwin Juli Rakhmadi et al., "Frequency-Based Analysis of Mosque Qibla Errors in Medan," *Al-Hilal: Journal of Islamic Astronomy* 7, no. 1 (2025): 37–50, https://doi.org/10.21580/AL-HILAL.2025.7.1.24203.

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Jama Mosque, India.

Figure 3. Jama Mosque, India

From the perspective of geospatial methodology and Islamic astronomy, these findings were obtained through a systematic workflow comprising three principal stages: the acquisition of the mosque's geographical coordinates using Google Earth, the calculation of the theoretical Qibla direction employing the Great Circle Bearing method, and the measurement of the mosque's observed orientation based on azimuth values derived from satellite imagery. This integrated approach enables the scientific and quantitative assessment of Qibla orientation deviations without the need for direct field observations. The measured deviation of 4.7° indicates a discernible difference between the architectural orientation of Jama Masjid and the astronomically determined direction of the Kaʿbah.[23]

From the perspective of Islamic astronomy (*ʿilm al-falak*), this deviation may be attributed to the Qibla

[23]Nurul Izza and Sartika Sartika, "Implementation of L-Qibla for Qibla Direction Indicators in Graves," *Astroislamica: Journal of Islamic Astronomy* 4, no. 1 (June 1, 2025): 142–61, https://doi.org/10.47766/ASTROISLAMICA.V4I1.3938.

determination methods commonly employed in India during earlier periods, which relied primarily on magnetic compass measurements and solar observations. While these methods represented important scientific practices of their time, they generally did not incorporate corrections for magnetic declination or employ spherical coordinate systems capable of providing greater positional accuracy. Consequently, modern measurements based on geospatial data reveal a modest discrepancy between the mosque's observed orientation and the astronomically calculated Qibla direction. Such a deviation can be regarded as a reasonable outcome given the technical limitations inherent in the classical methods available at the time of construction.

From a historical and architectural perspective, Jama Mosque stands as one of the most significant legacies of the Mughal Empire in the seventeenth century, embodying a harmonious integration of religious values and urban design traditions. The mosque was constructed during a period when Delhi had already developed into a well-organized urban center characterized by spatial layouts predominantly aligned along north–south and east–west axes. Consequently, the orientation of Jama Masjid appears to have been influenced not only by considerations of Qibla alignment but also by the prevailing urban grid and planning principles of the time, resulting in an orientation that is more closely aligned with the city's spatial structure than with the true Qibla direction.[24] This architectural configuration may be understood as an adaptation to the social and urban context of its time rather than as an indication of religious inconsistency. The Qibla deviation identified in this study illustrates how historical circumstances, urban planning practices, and the

[24]Alfira Rahma Fauziah, "Assessment of Qibla Direction Accuracy at Tanwir Mosque, Surabaya,Using Theodolite Measurements," *Astroislamica: Journal of Islamic Astronomy* 4, no. 2 (December 31, 2025): 371–94, https://doi.org/10.47766/astroislamica.v4i2.5163.

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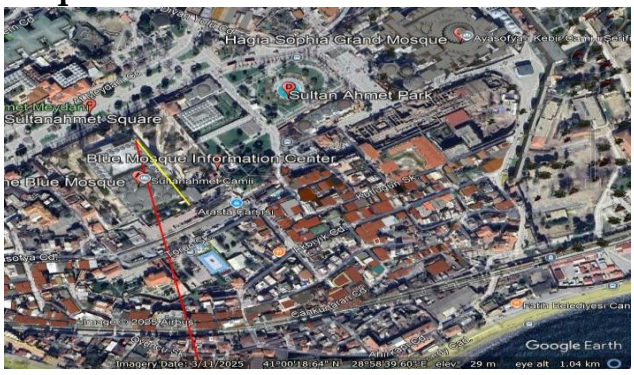
technological limitations of earlier periods collectively influenced the orientation of mosques across South Asia.[25]

The analysis of Jama Mosque further demonstrates the effectiveness of an integrated approach combining geospatial techniques and Islamic astronomy in evaluating the accuracy of Qibla orientations in historical mosques. By integrating satellite imagery-based digital measurements with astronomical calculations, this study not only quantifies the magnitude of Qibla deviation but also situates the findings within their relevant historical, architectural, and technological contexts. These results reinforce the broader conclusion of this study that modern geospatial technologies, such as Google Earth and QGIS, provide robust and reliable tools for reassessing and recalibrating the Qibla orientations of historical mosques. This is particularly significant in South Asia, where variations in mosque orientation may reflect the influence of non-astronomical factors, including historical urban planning, architectural traditions, and the technological constraints of earlier periods.

Blue Mosque Information Center.



[25]Ravik Walhidayah and Ismail Ismail, "Penentuan Azimut Kiblat Masjid Kampus UIN Sultanah Nahrasiyah Lhokseumawe Menggunakan Rumus Segitiga Bola Berbasis Python," *Astroislamica: Journal of Islamic Astronomy* 4, no. 2 (December 31, 2025): 276–94, https://doi.org/10.47766/astroislamica.v4i2.6012.

Figure 4. Blue Mosque, Turkey

As illustrated in Figure 4, the Blue Mosque geospatial visualization based on Google Earth satellite imagery reveals that the two azimuth lines the theoretical Qibla direction (yellow) and the observed building orientation (red)—are nearly coincident, with an angular deviation of only approximately 0.5°. Although the red line is slightly shifted westward relative to the yellow line, this discrepancy is minimal and can be considered astronomically insignificant. The theoretical Qibla direction, calculated using the Great Circle Bearing method, was determined to be 151°36′36″ measured clockwise from true north, whereas the observed orientation of the mosque was measured at approximately 150°50′. The close agreement between these values indicates that the Blue Mosque possesses an exceptionally high degree of Qibla orientation accuracy and may therefore be classified as exhibiting a very accurate alignment toward the Kaʿbah.[26]

These findings suggest that the Blue Mosque represents one of the most compelling examples of the application of Islamic astronomical principles in classical mosque architecture, where Qibla orientation was determined with a remarkable degree of precision through astronomical observations. The geospatial approach employed in this study provides clear evidence of the high level of Qibla accuracy achieved in mosques located to the north of the Kaʿbah, such as those in Turkey. Using high-resolution satellite imagery, the geographical position of the mosque was accurately determined based on latitude and longitude coordinates referenced to the WGS 84 geodetic system. The theoretical Qibla direction was

[26]Aindana Zulfa and Riza Afrian Mustaqim, "Method For Determining the Qiblat Direction of The Mosque: Analysis of Determining the Qibla Direction of the Al-Islahiyah Mosque, Gampong Lambhuk, Ulee Kareng District, Banda Aceh City," *Astroislamica: Journal of Islamic Astronomy* 3, no. 2 (December 1, 2024): 171–92, https://doi.org/10.47766/astroislamica.v3i2.3442.

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subsequently calculated using the Great Circle Bearing method derived from spherical trigonometry and compared with the mosque's observed orientation obtained through azimuth measurements in Google Earth Pro. The measured deviation of only 0.5° confirms the effectiveness of integrating geospatial techniques with Islamic astronomy for the quantitative assessment and validation of Qibla orientation. The exceptional accuracy observed at the Blue Mosque may also be interpreted in light of Turkey's geographical position relative to Makkah. Owing to its comparatively moderate longitudinal separation from the Kaʿbah, the sensitivity of Qibla calculations to positional uncertainties is reduced, thereby minimizing the potential for orientation errors arising from geographical variations.[27]

From a historical perspective, the remarkable accuracy of the Blue Mosque's Qibla orientation is closely associated with the rich scientific tradition of the Ottoman Empire, which fostered significant advancements in astronomy and *ʿilm al-falak* (Islamic astronomy). During this period, scholars, court astronomers, and architects developed increasingly sophisticated methods for determining the Qibla, drawing upon systematic observations of celestial bodies, including the Sun and the Pole Star (Polaris), to achieve precise spatial orientations prior to the construction of major religious buildings. The architectural legacy of figures such as Mimar Sinan and the scientific practices established during and after his era greatly influenced the standards of precision adopted in Ottoman mosque architecture. These astronomical observations were often complemented by practical

[27]Nur Mahmudi Qiromi, Ahmad Izzuddin, and M. Basthoni, "An Analysis of Qibla Direction Tolerance According to Sheikh Muhammad Yasin Al-Fadani: A Solution to Qibla Deviation," *Astroislamica: Journal of Islamic Astronomy* 5, no. 1 (June 5, 2026): 49–70, https://doi.org/10.47766/ASTROISLAMICA.V5I1.6223.

geodetic techniques employing instruments such as the astrolabe and quadrant, which enabled more accurate measurements of celestial positions and terrestrial directions. The integration of observational astronomy with early geodetic methods provided a robust scientific foundation for Qibla determination, contributing to the exceptional orientation accuracy observed in many Ottoman mosques, including the Blue Mosque.

The findings of this study demonstrate that the integration of traditional Islamic astronomy (ʿilm al-falak) with architectural expertise has played a significant role in producing mosque structures that are precisely aligned with the direction of the Kaʿbah. In this regard, the Blue Mosque not only represents an outstanding example of Islamic aesthetic achievement but also serves as a concrete manifestation of the successful application of Islamic scientific knowledge in both religious practice and architectural design.[28]

Furthermore, the results obtained from the Blue Mosque reinforce the broader conclusion of this study that advancements in astronomical knowledge, together with the adoption of modern positioning and measurement technologies, have a direct impact on the accuracy of Qibla orientation across different regions. Within this research framework, the quantitative descriptive approach, based on a systematic comparison between theoretical and observed Qibla directions provides an objective and scientifically grounded means of assessing orientation precision. These findings may serve as a reference for validating the Qibla orientation of other historical mosques in Europe and West Asia, while also contributing to the development of geospatially based Qibla determination models. More broadly, the case of the Blue Mosque in

[28]Saddam Hussain, Zheng Chunrou, and Fu Juan, "The Mosque's Primary Spaces and The Required Direction of The Mosque Building," *Journal of Islamic Architecture* 7, no. 4 (December 30, 2023): 719–35, https://doi.org/10.18860/jia.v7i4.21497.

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Istanbul illustrates that the integration of classical Islamic astronomical methods with contemporary digital technologies enables the sustained accuracy of Qibla orientation across different historical periods and technological regimes.

The geospatial visualization further reinforces the finding that Qibla orientation accuracy is primarily influenced by two key factors: (1) the geographical distance from Makkah, and (2) the methodological approach employed in determining the direction. Regions located closer to the Kaʿbah, such as Turkey and Egypt, exhibit minimal deviations, whereas more distant regions, including India and Kenya, tend to show slightly larger orientation discrepancies. The integration of geospatial data with Islamic astronomical approaches enables both visual and quantitative identification of these deviations in a systematic manner. Accordingly, the use of satellite imagery in Qibla-related studies not only enhances measurement precision but also contributes significantly to the preservation and documentation of Islamic architectural identity, which is fundamentally oriented toward spatial accuracy in religious practice.

Overall, the results of the Islamic astronomical calculations indicate that the average Qibla deviation across the four studied regions ranges from 0.1° to 7°. A general tendency is observed in which the magnitude of deviation increases with greater geographical distance from Makkah, as well as variations in the methodological approaches used for Qibla determination. The comparison between theoretical Qibla directions and satellite imagery further demonstrates that modern geospatial technologies provide a more precise means of correcting and validating Qibla orientation. At the same time, these findings also confirm the continued relevance and robustness of Islamic astronomical methods when situated within a global

analytical framework, particularly when integrated with contemporary geospatial measurement systems.

CONCLUSION

In conclusion, the orientation of mosques toward the Qibla across the studied regions demonstrates a consistently high level of accuracy, with an average deviation of less than 3°. This precision is shaped by a combination of factors, including geographical proximity to Makkah—where mosques located closer to the Kaʿbah show deviations as low as 0.1° to 0.5°—and increasing distances associated with slightly higher deviations ranging from 3° to 4.7°, as well as differences in methodological approaches and local architectural practices. The findings confirm that the integration of satellite-based geospatial technologies with Islamic astronomical (*falakiyah*) methods provides a precise, efficient, and objective framework for validating Qibla orientation, including in historical mosques where direct field measurements are not feasible. Beyond demonstrating methodological effectiveness, this study highlights the importance of tools such as Google Earth and QGIS in supporting the development of a comprehensive global spatial database of Qibla directions. Future research is encouraged to extend the geographical coverage across multiple continents and to incorporate advanced surveying technologies, such as drone-based photogrammetry and high-precision GPS measurements, to improve spatial accuracy and data resolution. Furthermore, strengthening interdisciplinary collaboration between Islamic astronomy, architectural studies, and Geographic Information Systems (GIS) will be essential for preserving the accuracy of Qibla orientation in historical mosques and guiding the design of future mosque architecture.

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