

Interpreting *Fajr Šādiq* Observations for Dawn Prayer Time Determination: A Comparative Atmospheric Framework Using Köppen Classification in Indonesia

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Abstract: Accurate determination of the dawn prayer (*ṣubḥ*) time is dependent on the correct identification of *fajr šādiq*. Regardless of this fact, observational results remain inconsistent, owing to differences in observational methods and atmospheric conditions. Therefore, this study investigates *fajr šādiq* using AstroImageJ image analysis and Sky Quality Meter (SQM) measurements at three Indonesian locations representing Equatorial, Monsoon, and Savanna climates according to the Köppen classification. To achieve this objective, we collected sequential dawn images and sky brightness data simultaneously and analysed them independently. AstroImageJ consistently identified *fajr šādiq* at a solar depression angle of approximately -19° across all sites, while SQM measurements showed greater variability. These results suggest that *fajr šādiq* observations should be interpreted by considering observational methods and atmospheric characteristics alongside astronomical parameters. By introducing the Köppen climate classification as a comparative framework, this investigation advances understanding of astronomical parameters as scientific representations that support Islamic legal reasoning in determining the beginning of the dawn prayer, while preserving its normative foundations.

Keywords: *fajr šādiq*; dawn prayer time; Köppen climate classification; astronomical observation; Islamic legal reasoning.

1. Introduction

Prayer is a fundamental component of Islamic worship, and its observance is governed by specific times determined by the position and apparent movement of celestial bodies. Accurately determining these prayer times is essential to Islamic practice, as the validity of each prayer is closely tied to its prescribed time. Accordingly, understanding the astronomical phenomena and indicators that mark the beginning and end of each prayer

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period is both religiously and scientifically significant.¹ A plausible indicator in this context is the appearance of *fajr ṣādiq* (true dawn), which marks the beginning of the dawn prayer (*ṣubḥ*) time and the start of the fasting obligation. Although *fajr ṣādiq* is related to the Sun's position below the horizon, identifying it depends not only on astronomical parameters but also on atmospheric conditions that shape the appearance of light on the eastern horizon.² These factors ensure that the observation of *fajr ṣādiq* remains a focus of contemporary Islamic astronomical studies, as part of efforts to enhance the accuracy of determining the start of the dawn prayer time.

Regardless of the fact that *fajr ṣādiq* has long been accepted as the astronomical indicator for the onset of the dawn prayer time, determining the exact moment of its appearance remains a significant issue in contemporary Islamic astronomical studies. Observational investigations in Indonesia and other countries suggest that efforts to identify *fajr ṣādiq* have not yielded consistent conclusions about the characteristics of its appearance.³ One area of divergence concerns the criteria for the Sun's altitude as an astronomical indicator for the start of the dawn prayer, specifically the criterion of the Sun being 20° below the horizon, which Indonesia has adopted as its national standard.⁴ These differing observational results have sparked scholarly debate and drawn public attention, particularly through coverage in *Qiblati* magazine.⁵ These dynamics show that

¹ Muslim ibn al-Ḥajjāj, *Ṣaḥīḥ Muslim*, II (Dār al-Kutub al-ʿIlmiyyah, 1992), 427.

² Ahmad Izzuddin, *Ilmu Falak Praktis* (Pustaka Rizki Putra, 2012), 78–79; Ahmad Izzuddin, *Fiqh Hisab Rukyat* (Erlangga, 2007), 38–39.

³ M. Basthoni, *Efek Polusi Cahaya Terhadap Penentuan Awal Waktu Subuh Di Indonesia*, (Semarang), 2022; Ismail Fahmi et al., “Zodiacal Light and Astronomical Twilight Measurement at Timau Nasional Observatory Site,” 3074, no. 1 (2024): 1–7, <https://doi.org/10.1063/5.0211329>; Tono Saksono and Mohamad Ali Fulazzaky, “Predicting The Accurate Period of True Dawn Using A Third-Degree Polynomial Model,” *NRIAG Journal of Astronomy and Geophysics* 9, no. 1 (2020): 238–44, <https://doi.org/10.1080/20909977.2020.1738106>; Nihayatur Rohmah, “The Effect of Atmospheric Humidity Level to the Determination of Islamic Fajr/Morning Prayer Time and Twilight Appearance,” *Journal of Physics: Conference Series* 771 (November 2016): 012048–012048, <https://doi.org/10.1088/1742-6596/771/1/012048>; Hendro Setyanto et al., “Zodiac Light Detection Based on Sky Quality Meter (SQM) Data: Preliminary Study,” *Al-Hilal: Journal of Islamic Astronomy* 3, no. 1 (2021): 121–34, <https://doi.org/10.1086/676819>; A. W. Raihana et al., “Issues on Determination Of-Accurate Fajr and Dhuha Prayer Times According to Fiqh and Astronomical Perspectives in Malaysia: A Bibliography Study,” 18 (October 2016): 675–80.

⁴ Departemen Agama RI, *Pedoman Penentuan Jadwal Waktu Shalat Sepanjang Masa* (Direktorat Pembinaan Badan Peradilan Agama Islam, 1994), 32; Arwin Juli Rakhmadi Butar-butur, *Fajar Dan Syafaq Dalam Keserjanaan Astronom Muslim Dan Ulama Nusantara*, 1st ed. (LKIS, 2018), 131–33.

⁵ Mamduh Farhan Al-Buhairi, “Salah Kaprah Waktu Subuh,” *Qiblati* (Malang), May 2009; Imam Qusthalaani, “Kajian Fajar Dan Syafaq Perspektif Fikih Dan Astronomi,” *Jurnal Kajian Hukum Islam* 1, no. 1 (2018).

determining *fajr ṣādiq* requires ongoing empirical testing to better understand the factors influencing its appearance.

The study of *fajr ṣādiq* has evolved from a narrow focus to increasingly diverse approaches. Initially, this body of inquiry developed within the *fiqh* tradition, relying on interpretations of the Qur'an and Hadith, as well as jurists' views, to define *fajr ṣādiq* as the marker for the onset of dawn prayer time.⁶ With advances in modern Islamic astronomy, research on *fajr ṣādiq* has expanded to include empirical methods ranging from direct astronomical observation to photometric instruments such as the Sky Quality Meter (SQM), digital photography, and image analysis software, all aimed at improving dawn-identification accuracy. More recently, some studies have also begun to consider the impact of environmental factors, particularly light pollution, on the quality of *fajr ṣādiq* observations.⁷ These diverse approaches have significantly enriched the understanding of *fajr ṣādiq* characteristics and improved the accuracy of determining the start time for the dawn prayer.

Various approaches have significantly improved the accuracy of *fajr ṣādiq* observations, but studies have largely focused on normative aspects, the development of observational instruments, and the impact of light pollution on dawn visibility. Atmospheric characteristics, which govern sunlight scattering, have received comparatively little attention as analytical variables for explaining variations in *fajr ṣādiq* observation results.⁸ From an atmospheric physics perspective, the light an observer receives results from the interaction between solar radiation and Earth's atmosphere through scattering; therefore, variations in atmospheric characteristics can affect both the intensity and visibility of dawn light.⁹ In light of this, investigating how atmospheric characteristics can explain variations in *fajr ṣādiq* observations, as part of broader efforts to strengthen the empirical basis for determining the start time of the dawn prayer, becomes pertinent.

A common method for systematically determining differences in atmospheric features is the Köppen climate classification.¹⁰ This system categorises regions by temperature and

⁶ Susiknan Azhari, "Tracing the Concept of Fajr in the Islam Mosaic and Modern Science," *AHKAM: Jurnal Ilmu Syariah* 18, no. 1 (2018): 219–32, <https://doi.org/10.15408/ajis.v18i1.9819>.

⁷ Ahmad Izzuddin and M. Basthoni, "Using Command-Line and Graphical User Interfaces Program in Determining Dawn in Pollutive and Non-Pollutive Area," *Webology* 19, no. 1 (2022): 5879–92.

⁸ Craig F. Bohren and Eugene E. Clothiaux, *Fundamentals of Atmospheric Radiation: An Introduction with 400 Problems*, 1st ed. (Wiley, 2006), <https://doi.org/10.1002/9783527618620>.

⁹ Kuo-Nan Liou, *An Introduction to Atmospheric Radiation*, 2nd ed. (Academic Press, 2002); John H. Seinfeld and Spyros N. Pandis, *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, 3rd ed. (Wiley, 2016); John M. Wallace and Peter V. Hobbs, *Atmospheric Science: An Introductory Survey*, 2nd ed. (Academic Press, 2006).

¹⁰ Wladimir Peter Koppen, *Das Geographische System Der Klimate* (Verlag von Gebruder Borntraeger, 1936); Michael Allaby, *Encyclopedia of Weather and Climate* (Facts on File, 2000).

precipitation patterns that reflect long-term climate conditions, making it a widely used comparative tool in climatology.¹¹ In this study, the Köppen system serves not as the primary subject of analysis but as an analytical framework for representing atmospheric differences across observation sites. Applying this classification is expected to broaden understanding of how *fajr ṣādiq* observations vary across regions with different climates, strengthening the empirical basis for identifying the dawn prayer's start time.

This study examines how climatic differences across Köppen zones affect *fajr ṣādiq* observations, using the Köppen climate classification as a comparative framework. By analysing observational data from different climate regions in Indonesia, this study aims to understand how atmospheric variations affect *fajr ṣādiq* sighting times. It focuses not only on pinpointing when *fajr ṣādiq* first appears but also on identifying the factors behind the observed differences. This approach is expected to expand the understanding of *fajr ṣādiq* observation and enhance the empirical basis for determining the dawn prayer's start time.

Through this approach, the study broadens the perspective on *fajr ṣādiq* by using atmospheric characteristics as an analytical lens to explain variations in observational data and applying the Köppen climate classification as a comparative framework to represent atmospheric differences across observation sites. Therefore, this exploration is expected to enrich the empirical foundation and academic discourse on determining the start time for the dawn prayer in Indonesia, while opening avenues for future investigations covering wider geographical areas and longer observation periods.

2. Methods

The present study used a comparative observational approach to examine how *fajr ṣādiq* observations vary across locations in Indonesia with different climate types. Rather than simply comparing observation results from various sites, the investigation aimed to understand how climatic differences might explain variations in the appearance of *fajr ṣādiq*. To achieve this, astronomical observations, sky brightness measurements, and digital image analysis were combined, applying the Köppen climate classification as a framework for interpreting differences between locations with distinct atmospheric features.

The observation sites were deliberately selected to represent different tropical climate types according to the Köppen classification, which served as the basis for comparison

¹¹ Markus Kotteck et al., "World Map of the Köppen-Geiger Climate Classification Updated," *Meteorologische Zeitschrift* 15, no. 3 (2006): 259–63, <https://doi.org/10.1127/0941-2948/2006/0130>; M. C. Peel et al., "Updated World Map of the Köppen-Geiger Climate Classification," *Hydrology and Earth System Sciences* 11, no. 5 (2007): 1633–44, <https://doi.org/10.5194/hess-11-1633-2007>.

throughout the study. This approach enabled comparisons of *fajr ṣādiq* observations across locations with distinct climate features, which served as indicators of variations in atmospheric conditions. Additionally, sites were selected for their relatively low light pollution to minimise its impact on dawn visibility. Observations were accordingly carried out at Mahameru, Lebakbarang (Pekalongan) for the tropical rainforest climate (Af); Balongan Indah Beach (Indramayu) for the tropical monsoon climate (Am); and Bilik Dua Beach, Baluran National Park (Situbondo) for the tropical savanna climate (Aw).

At each observation site, sky brightness was measured simultaneously with a Sky Quality Meter (SQM) and a Xiaomi 12T smartphone mounted on a stable tripod. The smartphone captured a continuous sequence of pre-dawn images, while the SQM recorded sky brightness changes independently throughout the observation period. To ensure consistency across sites, we kept all camera settings constant, including exposure, ISO, shutter speed, white balance, focus, and image interval. The resulting image sequences were analysed with AstroImageJ to identify the appearance of *fajr ṣādiq* based on brightness changes,¹² while the SQM data were processed separately to track corresponding sky brightness variations.¹³ We then compared these results to assess how effectively both methods identified *fajr ṣādiq*. The results were subsequently analysed in a descriptive and comparative manner, using the Köppen climate classification as an atmospheric framework to examine how differences in atmospheric conditions may shape the interpretation of *fajr ṣādiq* observations across the three study locations.

3. Results and Discussion

3.1. Characteristics of Observation Sites and Initial Observation Results

Observations of *fajr ṣādiq* were conducted at three sites in Indonesia, each representing a distinct Köppen climate type, namely Lebakbarang in Pekalongan Regency (Af), Balongan Indah Beach in Indramayu Regency (Am), and Bilik Dua Beach within Baluran National Park, Situbondo Regency (Aw). The locations are shown in Figure 1, with site conditions detailed in Figure 2. Comprising forested mountains in Lebakbarang, the monsoonal coast of Indramayu, and the coastal savanna of Baluran, these environments provide a diverse and well-differentiated basis for comparing *fajr ṣādiq* observation results.

¹² Karen A. Collins et al., “Astroimagej: Image Processing And Photometric Extraction For Ultra-Precise Astronomical Light Curves,” *The Astronomical Journal* 153, no. 2 (2017): 77, <https://doi.org/10.3847/1538-3881/153/2/77>.

¹³ Di-Fu Guo et al., “Sky Brightness at Weihai Observatory of Shandong University,” *Publications of the Astronomical Society of the Pacific* 126, no. 939 (2014): 496–503, <https://doi.org/10.1086/676819>.

Figure 1. Observation Sites Across Indonesia

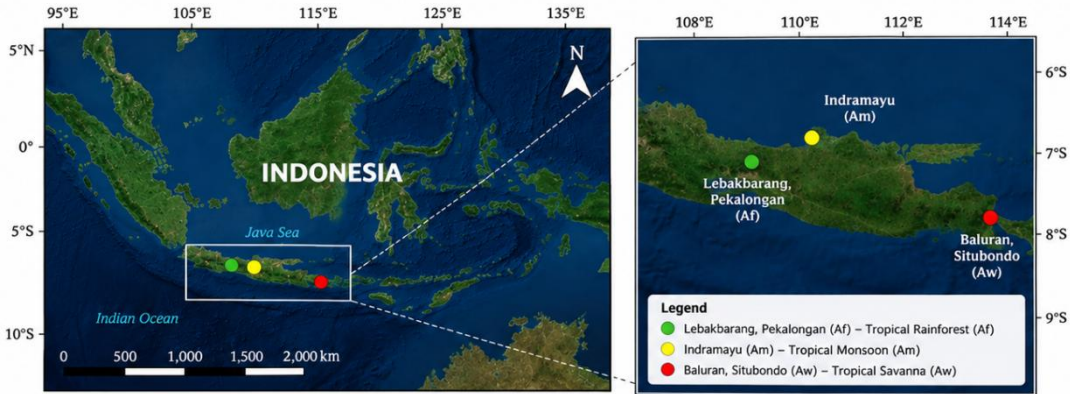
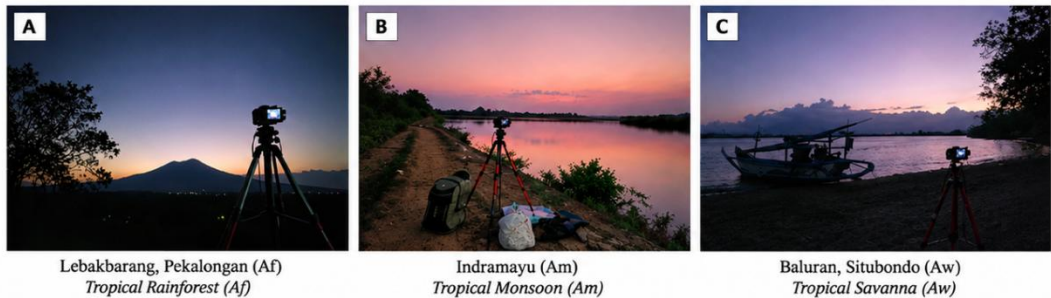


Figure 2. Site Conditions



Note: (A) Lebakbarang represents the Af climate zone, (B) Indramayu represents the Am climate zone, and (C) Baluran represents the Aw climate zone.

Data collected across the three sites provided measurements of *fajr ṣādiq* appearance obtained through a Sky Quality Meter (SQM) and analysed with AstroImageJ. The results, summarised in Table 1, show variations in the timing of *fajr ṣādiq* and differing sky-brightness patterns across the sites, providing the basis for a comparative analysis of how *fajr ṣādiq* observations relate to climate types classified by the Köppen system.

Table 1. *Fajr Ṣādiq* Observation Results

Observation Site	Köppen Climate	AstroImageJ (Solar Depression Angle)	SQM (Solar Depression Angle)
Pekalongan	<i>Af (tropical rainforest)</i>	−18°40′19″	−17°18′03″
Indramayu	<i>Am (tropical monsoon)</i>	−18°43′09″	−19°27′46″
Situbondo	<i>Aw (tropical savanna)</i>	−18°50′32″	−18°7′40.8″

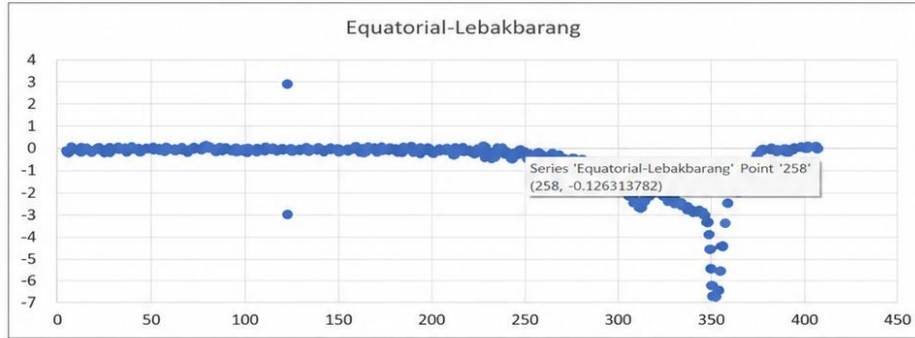
Source: Author Framework, 2025

Table 1 summarises observations of *fajr ṣādiq* at three sites representing Köppen climate types Af, Am, and Aw, using two methods, namely, AstroImageJ and the Sky Quality Meter (SQM). Both approaches generally detected the start of *fajr ṣādiq* at all locations, although each produced different Sun depression angles. AstroImageJ recorded a narrow range between −18°40′19″ and −18°50′32″, while SQM measurements varied from

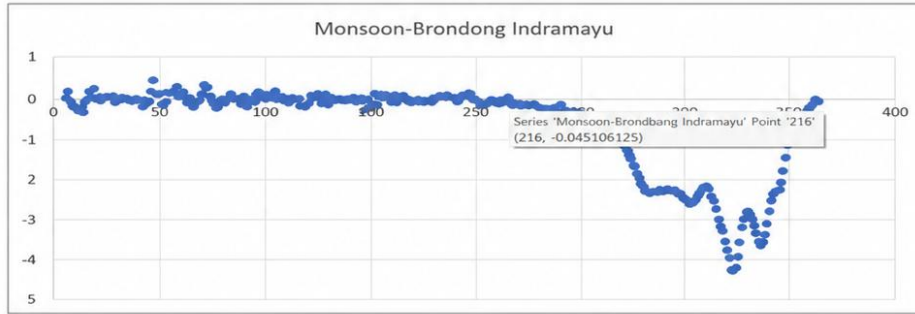
–17°18'03" to –19°27'46". Figure 3 shows how image analysis identified *fajr ṣādiq* by tracking brightness changes over time, as measured with AstroImageJ.

Figure 3. Temporal Changes in Image Brightness Prior to the Appearance of *fajr ṣādiq* Derived from AstroImageJ Analysis

(A) Equatorial Climate (Af) – Lebakbarang, Pekalongan



(B) Monsoon Climate (Am) – Brondong Beach, Indramayu



(C) Tropical Savanna Climate (Aw) – Bilik Dua Beach, Baluran National Park

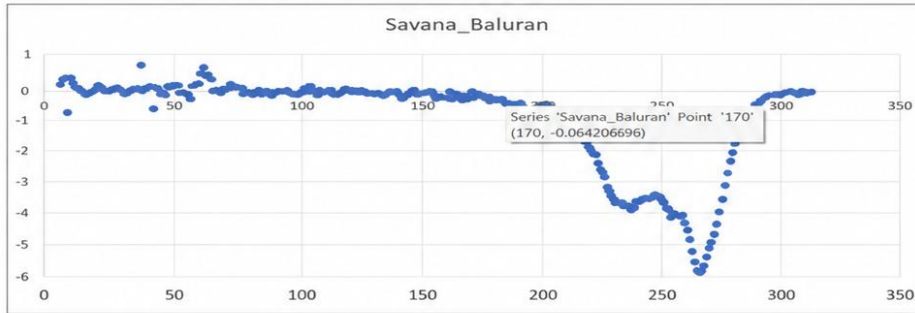


Figure 3 shows changes in light intensity recorded by AstroImageJ at three observation sites. At each site, intensity remained fairly stable for most of the sequence before gradually decreasing toward *fajr ṣādiq*. The marked points in each panel signify the start of *fajr ṣādiq*, identified in the 258th image for Lebakbarang, the 216th for Indramayu, and the 170th for Baluran. Although the collective pattern is consistent across sites, the post-detection curves differ in shape, reflecting distinct atmospheric conditions at each location. Figure 4 compares these observations with sky brightness measurements obtained using a Sky Quality Meter (SQM).

Figure 4. Temporal Changes in Sky Brightness Prior to Appearance of *Fajr Şādiq*
Derived from SQM Analysis

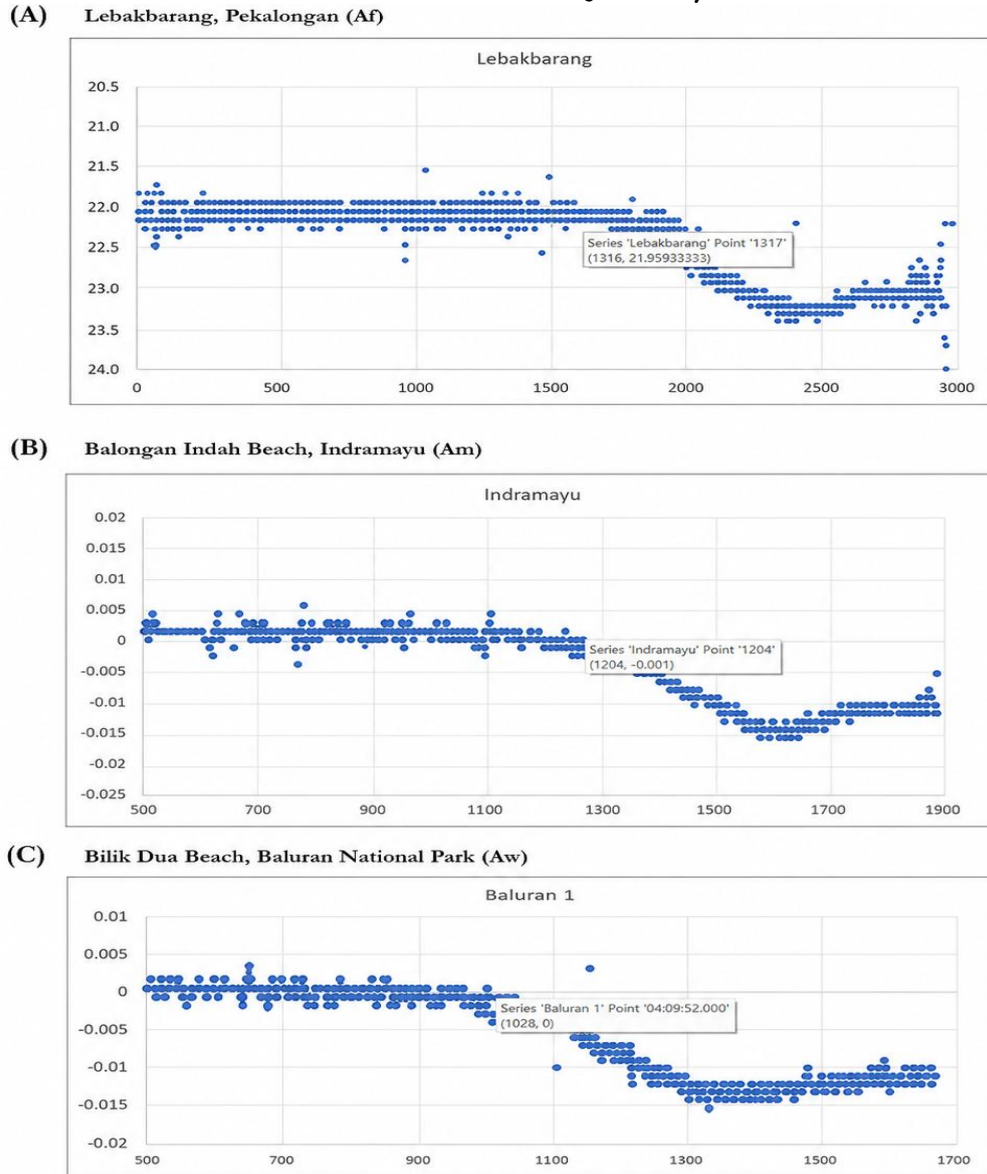


Figure 4 reflects how sky brightness varied at three observation sites as measured by the SQM. All curves show a general trend of increasing brightness as dawn approaches, although the transition patterns differ from those observed in the AstroImageJ analysis. This variation confirms that both methods detect the same phenomenon using different parameters, explaining the differences in curve features between the two approaches.

3.2. Consistency of Image-Based and SQM-Based Observations

The observational data show that both AstroImageJ and the Sky Quality Meter (SQM) successfully identified the onset of *fajr şādiq* at all three study locations. However, the

obtained results reflected distinct patterns. AstroImageJ recorded a relatively consistent range of solar depression angles, while SQM measurements exhibited more variation. This difference suggests the two methods perceive the appearance of *fajr ṣādiq* in fundamentally different ways. The following discussion examines the reasons for these differences and their implications for dawn observations and prayer timing. The consistency of results obtained through AstroImageJ shows that image-based analysis can identify the onset of *fajr ṣādiq* through gradual changes in sky brightness, rather than relying on a single measurement at a specific moment. This approach detects the onset of *fajr ṣādiq* by observing temporal patterns of light-intensity changes across a sequence of images captured successively and analysed using AstroImageJ.¹⁴ In this study, we acquired all images using identical equipment and camera settings at each observation site to minimise variations from instrument configuration. The consistent results produced by AstroImageJ therefore suggest that this image-analysis approach can provide a more stable identification of *fajr ṣādiq* across diverse climatic conditions, although further testing with calibrated photometric instruments is still needed to evaluate the reproducibility of these results.

Dissimilar to AstroImageJ, the SQM measurements showed greater variation in the Sun's depression angle across the three sites. This outcome is expected, as SQM directly measures sky brightness by capturing the combined effects of multiple light sources reaching its sensor. Local atmospheric factors, such as transparency, scattering, thin clouds, and ambient sky brightness, all affect these readings after dawn. Therefore, differences in SQM results reflect environmental sensitivity during observation rather than instrument error, allowing the SQM to capture atmospheric differences at each location and offer additional insight into how environmental factors shape the appearance of *fajr ṣādiq*.

The results suggest that AstroImageJ and the SQM should be viewed not as competing methods but as complementary approaches. AstroImageJ provides a relatively consistent identification of the onset of *fajr ṣādiq* by analysing changes in image intensity, while the SQM offers information on sky brightness dynamics shaped by environmental conditions during the observation process.¹⁵ Using both methods

¹⁴ F. Patat et al., "UBVRI Twilight Sky Brightness at ESO-Paranal," *Astronomy & Astrophysics* 455, no. 1 (2006): 385–93, <https://doi.org/10.1051/0004-6361:20064992>; Rusli Rusli et al., "Determination Dawn of Shadiq in Masalembu Island by Using Image Processing Sobel Edge Detection Technique," August 12, 2021, 57–66; Collins et al., "ASTROIMAGEJ"; M. Hasan Faadillah et al., "Workshop on Young Crescent Moon: Visibility Limit and Digital Image Contrast," *Journal of Physics: Conference Series* 2773, no. 1 (2024): 012025, <https://doi.org/10.1088/1742-6596/2773/1/012025>.

¹⁵ Pietro Fiorentin et al., "SQM Ageing and Atmospheric Conditions: How Do They Affect the Long-Term Trend of Night Sky Brightness Measurements?," *Sensors* 25, no. 2 (2025): 516, <https://doi.org/10.3390/s25020516>.

simultaneously produced a more comprehensive understanding of *fajr ṣādiq* onset characteristics than relying on either technique alone.

3.3. Influence of Köppen Climate on Fajr Ṣādiq Observation

Current studies on *fajr ṣādiq* primarily emphasise astronomical factors, with limited use of the Köppen climate classification as a comparative tool for interpreting observational data. In contrast, this study assumes that atmospheric features could affect the timing of *fajr ṣādiq*. It recognises that although the dawn phenomenon occurs globally, regional atmospheric variations, such as differences in climate, humidity, cloud cover, and aerosols, shape the conditions under which observations are made. The Köppen classification is therefore applied to compare environmental conditions across observation locations, rather than as a direct determinant of *fajr ṣādiq* time.

The results show that atmospheric features, as classified by the Köppen system, had a more pronounced effect on SQM measurements than on image-based analyses. Although AstroImageJ produced similar solar depression angles across all three sites despite their differing climate types, SQM data showed greater variation between locations. This pattern suggests that atmospheric differences affect sky brightness measurements more directly than they affect detecting *fajr ṣādiq* through image brightness changes. The Köppen classification thus serves not only to describe each site's climate but also to provide a useful framework for comparing how *fajr ṣādiq* observations vary across environments with distinct atmospheric conditions.

The response differences observed between AstroImageJ and the SQM stem from their distinct operating principles. The SQM directly measures sky brightness, capturing light that has undergone various atmospheric effects before reaching the sensor, and factors such as atmospheric transparency, aerosol levels, humidity, and scattering during twilight can all affect its readings.¹⁶ AstroImageJ, by comparison, uses image-based analysis to detect changes in light-intensity patterns over a series of images, depending more on consistent visual changes than on absolute brightness levels at specific moments.¹⁷ These differences in operating principle explain why

¹⁶ Siyue Zheng et al., "Machine-Learning-Based Monitoring of Night Sky Brightness Using Sky Quality Meters and Multi-Source Remote Sensing," *Remote Sensing* 17, no. 8 (2025): 1332, <https://doi.org/10.3390/rs17081332>; Fiorentin et al., "SQM Ageing and Atmospheric Conditions"; Krzysztof Skarżyński and Maciej Lach, "Using a Single Sky Quality Meter for Simplified Light Pollution Changes Analysis Across a Big City," *IEEE Instrumentation & Measurement Magazine* 27, no. 3 (2024): 43–49, <https://doi.org/10.1109/MIM.2024.10505188>.

¹⁷ Collins et al., "ASTROIMAGEJ"; Shen Xinming, "'The Reddish Moon'--The Evaluation of Urban Air Pollution by Lunar Extinction," *Journal of Physics: Conference Series* 2012, no. 1 (2021): 012128, <https://doi.org/10.1088/1742-6596/2012/1/012128>.

AstroImageJ results tend to be more uniform, while SQM data show greater variability across the three locations.

This study suggests that the Köppen classification can serve as a useful comparative tool in *fajr ṣādiq* observational investigations, particularly for understanding variations across different observation methods. Rather than directly determining the time of *fajr ṣādiq*, it represents the atmospheric conditions affecting the observation process, broadening the traditional focus of *fajr ṣādiq* study beyond purely astronomical factors. Future studies could incorporate climatic and atmospheric variables when planning observations or analysing dawn data. These results should also be considered alongside existing explorations on *fajr ṣādiq* to better understand how regional differences in reported solar depression angles relate to observational techniques and atmospheric conditions.

3.4. Implications for Islamic Legal Reasoning on the Determination of Fajr Prayer Time

Studies on identifying *fajr ṣādiq* have shown that pinpointing the start time of the dawn prayer is an evolving field, advancing alongside new astronomical observation techniques. Previous studies have used various methods, including visual observation, digital photography, sky brightness measurements with Sky Quality Meters (SQM), and software tools such as AstroImageJ for image analysis. These developments confirm that differences in instruments, analysis methods, and atmospheric conditions can affect how *fajr ṣādiq* appears.¹⁸ This investigation contributes to the discussion by comparing three regions with different Köppen climate types and highlighting the role of atmospheric factors in interpreting astronomical data. As observational methods continue to advance, they not only expand empirical knowledge about *fajr ṣādiq* but also show that the scientific parameters used to understand it remain subject to refinement through ongoing data collection. This progress invites reflection on how scientific advancements shape both observational techniques and Islamic legal understanding of the indicators used to determine the start of dawn.

The basis for determining the start of the dawn prayer time is explicitly grounded in the Qur'an and Hadith, where the appearance of *fajr ṣādiq* signals its beginning. Considering this perspective, astronomical parameters such as the Sun's depression angle are not direct legal norms; rather, they are scientific tools applied to observe the

¹⁸ Izzuddin and Basthoni, "Using Command-Line and Graphical User Interfaces Program in Determining Dawn in Pollutive and Non-Pollutive Area"; Fahmi et al., "Zodiacal Light and Astronomical Twilight Measurement at Timau Nasional Observatory Site"; Basthoni, *Efek Polusi Cahaya Terhadap Penentuan Awal Waktu Subuh Di Indonesia*; Setyanto et al., "Zodiac Light Detection Based on Sky Quality Meter (SQM) Data: Preliminary Study"; Saksono and Fulazzaky, "Predicting The Accurate Period of True Dawn Using A Third-Degree Polynomial Model."

natural phenomena described in religious texts in a more objective manner.¹⁹ Studies show that these scientific models can be refined through improved observational techniques, technological advances, and more extensive empirical data. Within this framework, scientific progress aims not to alter Sharia rulings but to improve the precision with which Islamic law identifies the natural events underlying it. This orientation corresponds with Barbour's dialogue model, which regards religion and science as distinct but mutually informing domains of knowledge, each capable of enriching the other's understanding of reality.²⁰ Accordingly, Islamic legal sources designate *fajr ṣādiq* as the normative indicator for prayer time, while astronomy furnishes the observational means and scientific parameters to recognise the event empirically. Variations in observations attributable to atmospheric conditions or technological development do not alter the Sharia norm; they refine the scientific representations used to locate the natural phenomenon on which the legal ruling rests. This productive dialogue confirms that scientific development does not override divine revelation but deepens understanding of the empirical facts relevant to Islamic law.

Beyond clarifying the dialogue between religion and science, the results carry methodological implications for Islamic legal reasoning. While Barbour addresses how scientific knowledge and religious norms may interact, Islamic legal methodology offers a framework for understanding how empirical knowledge contributes to applying legal norms. As Hallaq notes, Islamic legal reasoning is tied to developments in understanding current realities and requires a thorough grasp of the facts underlying legal judgments.²¹ Astronomical observations, for instance, do not modify the normative rules governing *fajr ṣādiq* when determining the start of the dawn prayer, but deepen understanding of the empirical signals marking the beginning of prayer time. This methodological orientation corresponds with the classical *uṣūl al-fiqh* concept of *taḥqīq al-manāṭ*.²²

¹⁹ Badrun Taman et al., "Time-Related Rulings in Fiqh Munakahat: A Contemporary Integration of Astronomical and Jurisprudential Analysis," *MILRev: Metro Islamic Law Review* 4, no. 2 (2025): 797–821, <https://doi.org/10.32332/8pvnz650>.

²⁰ Ian G. Barbour, *Religion and Science: Historical and Contemporary Issues* (HarperCollins, 1997), 90–98; Stefano Bigliardi, "Barbour's Typologies and The Contemporary Debate on Islam and Science," *Zygon: Journal of Religion and Science* 47, no. 3 (2012): 501–19, <https://doi.org/10.1111/j.1467-9744.2012.01269.x>; Saiful Hadi et al., "The Challenge of Integrating Science and Religion in Indonesia and Malaysia," *Teosofi: Jurnal Tasawuf Dan Pemikiran Islam* 14, no. 1 (2024): 96–122, <https://doi.org/10.15642/teosofi.2024.14.1.96-122>.

²¹ Wael B. Hallaq, *Sharia: Theory, Practice and Transformation* (Cambridge University Press, 2009), 78–79; Rahmat Budiman, "Theoretical Review of Islamic Legal Sources According to The Nisrepresentation Theory of Hallaq," *PETITA: JURNAL KAJIAN ILMU HUKUM DAN SYARIAH* 5, no. 2 (2020), <https://doi.org/10.22373/petita.v5i2.100>.

²² Abū Hāmid al-Ghazālī, *Al-Mustasfā* (Dār al-Kutub al-ʿIlmiyyah, 2022), 437; Abū Ishāq ash-Shāṭibī, *Al-Muwāfaqāt Fī Uṣūl al-Fiqh* (Dār al-Kutub al-ʿIlmiyyah, n.d.), 774–75.

Improvements in observational techniques and astronomical precision therefore aim to identify these facts more accurately, not to alter the law.²³

The results do not propose revising the legal standards for the start time of the dawn prayer. Rather, the findings aim to strengthen the empirical evidence that enables a more precise application of existing norms. An improved scientific understanding of the appearance of *fajr ṣādiq* can support the development of prayer timetables that more accurately correspond to the astronomical phenomena described in religious texts. Through the lens of *maqāṣid al-shari'ah*, refining the accuracy of worship timing constitutes part of the effort to protect the observance of worship (*ḥifẓ al-dīn*) through scientific progress.²⁴ However, empirical results should not automatically translate into policy changes regarding prayer times; rather, they contribute to academic discussion and may inform broader deliberations by religious authorities.

4. Conclusion

In conclusion, this study examined the onset of *fajr ṣādiq* through two observational methods, namely AstroImageJ image analysis and sky brightness measurement with a Sky Quality Meter (SQM), conducted at three locations representing different Köppen climate zones. The obtained results showed that AstroImageJ consistently identified *fajr ṣādiq* at a solar depression angle of approximately -19° , while SQM measurements varied more considerably. These differences confirm that interpreting *fajr ṣādiq* observations depends on the interplay of astronomical factors, observational methods, and atmospheric conditions present at each site.

The principal contribution of this study was twofold. It developed an observational approach to *fajr ṣādiq* by combining AstroImageJ image analysis, SQM measurements, and the Köppen climate classification as a comparative framework, while also providing an empirical and theoretical basis that enriches Islamic legal understanding of dawn prayer time. The results confirmed that astronomical parameters such as the solar depression angle serve as scientific indicators of the *fajr ṣādiq* phenomenon, and that these indicators can be progressively refined through improved observational techniques, new

²³ Muhammad Harfin Zuhdi et al., "Unifying the Hijri Calendar: A Fiqh al-Siyāsa Model for Legal Authority and Certainty," *Al-Ahkam* 36, no. 1 (2026): 165–90, <https://doi.org/10.21580/ahkam.2026.36.1.29009>.

²⁴ Muhammad al-Tāhir ibn Āsyūr, *Maqāṣid Al-Syari'ah al-Islāmīyah* (Dār al-Kitāb al-Maṣrī, 2011), 137; Jasser Auda, *Membumikan Hukum Islam Melalui Maqasid Syariah*, trans. Rosidin Rosidin and `Ali Abd el-Mun`im (Mizan Pustaka, 2008), 320; Ali Sodiqin, "Science-Based Ijtihad: Religious and Scientific Dialectic on Fatwas Regarding Congregational Worships amid the Covid-19 Pandemic," *Ijtihad: Jurnal Wacana Hukum Islam Dan Kemanusiaan* 21, no. 1 (2021): 79–98, <https://doi.org/10.18326/ijtihad.v21i1.79-98>; Adnan Adnan et al., "Science, Religion, and Religious Moderation in Al-Ghazali's Thought," *Journal of Islamic Thought and Philosophy* 5, no. 1 (2026): 1–23, <https://doi.org/10.15642/jitp.2026.5.1.1-23>.

technology, and accumulating empirical data, while preserving the normative foundation for prayer time drawn from the Qur'an and Sunnah. Advances in astronomical observation therefore not only improve the precision with which *fajr ṣādiq* is identified but also strengthen Islamic legal reasoning by deepening the understanding of the empirical foundations on which legal rulings rest.

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