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The Sun's Vertical Depression Effect on True Dawn: A Visual Observation Study

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ABSTRACT

This study aims to analyze the influence of the Sun's vertical depth on the appearance of true Dawn in Medan City using the naked-eye observation method. Observations in Medan show that the true dawn light first appears when the Sun is at a depression angle of −14° to −12° below the eastern horizon. The difference between the visible true Dawn and the official dawn time (-20°) is about 6°. These results are consistent with more than 30 studies conducted across over 10 countries at various latitudes, utilizing approximately five different monitoring methods. These results confirm the need to correct the dawn time based on local observations and actual sky conditions, so that the determination of the time of worship better aligns with astronomical reality.

ARTICLE INFO

ABSTRACT

Penelitian ini bertujuan untuk menganalisis pengaruh kedalaman vertikal Matahari terhadap kemunculan fajar sadik di Kota Medan menggunakan metode pengamatan mata telanjang. Hasil pengamatan di Medan menunjukkan bahwa cahaya fajar sadik pertama kali muncul ketika Matahari berada pada sudut depresi antara −14° hingga −12° di bawah ufuk timur. Selisih antara fajar sadik yang terlihat dengan waktu subuh resmi (-20°) adalah sekitar 6°. Hasil ini sejalan dengan lebih dari 30 penelitian yang dilakukan di lebih dari 10 negara pada berbagai lintang, menggunakan sekitar lima metode pemantauan yang berbeda. Hasil ini menegaskan perlunya mengoreksi waktu subuh

berdasarkan pengamatan lokal dan kondisi langit yang sebenarnya, sehingga penentuan waktu ibadah lebih sesuai dengan realitas astronomis.

INTRODUCTION

True Dawn is an important astronomical phenomenon in various aspects of life, especially in religious contexts such as determining the time of Fajr prayers for Muslims. Muslim countries used to rely on the athan, which was mainly based on visual cues to determine the time of the fajr prayer.[1] In shari'i terminology, Dawn is distinguished into Dawn kādzib, the vertical light that soon disappears, and true Dawn, the horizontal light that crosses the eastern horizon as a marker of the dawn time. Astronomically, Dawn is divided into three phases based on the angle of the Sun's depression below the horizon: astronomical Dawn (18°), nautical Dawn (12°), and civil Dawn (6°).[2] The appearance of true Dawn often differs from the theoretical definition. Local environmental factors, such as light pollution, humidity, temperature, and weather conditions, influence the apparent timing of Dawn. For example, high temperatures tend to bring on the Dawn in areas with large solar depressions.[3] In addition, light pollution in urban areas can impede visual observations of Dawn, so a local approach is needed to determine the time of Dawn, and observations should be taken in areas far from residential and industrial zones.[4] Medan City, one of Indonesia's major cities, has relatively high light pollution, especially in the downtown area.[5] It has a

[1]Abdul Haq Sultan, "Sun Apparent Motion and Salat Times," *Al-Irshaad* 08 (2004): 7–13.

[2]Muhammad Hadi Bashori, *Pengantar Ilmu Falak* (Jakarta: Pustaka al-Kautsar, 2015).

[3]Nihayatur Rohmah, "Pengaruh Suhu Dan Kelembaban Atmosfer Terhadap Ketampakan Fajar Shadiq," *Al-Mabsut: Jurnal Studi Islam Dan Sosial* 8, no. 2 (2014): 1–14.

[4]Marataon Ritonga, "Pengamatan Fajar Shadiq Menggunakan All Sky Camera Di Kota Medan" (UIN Walisongo Semarang, 2022).

[5]Hariyadi Putraga et al., "Analisis Peningkatan Polusi Cahaya Berdasarkan Pembacaan SQM Dan Citra Satelit VIIRS Tahun 2017 – 2022 Di Kota Medan," *AL - AFAQ : Jurnal Ilmu Falak Dan Astronomi* 5, no. 1 (2023): 28–41, https://doi.org/10.20414/afaq.v5i1.7250.

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relatively high level of light pollution, especially in the downtown area.[6] However, few studies have used direct visual observation methods.

The accuracy of Fajr time has long been a concern in modern Islamic astronomy. Several studies have shown that the official schedule of the Dawn time in some countries, including Indonesia and Egypt, tends to be too early compared with visual observations of the true Dawn. This discrepancy occurs because the standard for the Sun's altitude (vertical depression) used to calculate the time of Fajr often does not correspond to the actual sky conditions in the field. In Indonesia, for example, the Ministry of Religious Affairs still uses the −20° standard.[7] Meanwhile, empirical observations show that the light of Dawn is visible only within the range −15° to −14° at good visibility.[8] This difference can reach 10 to 15 minutes, with important implications for the validity of implementing the Fajr prayer.

A.H. Hassan also identified a similar phenomenon in his various studies under the National Research Institute of Astronomy and Geophysics (NRIAG), Egypt. Hassan (2018; 2019) found that the Fajr schedule that uses the −19.5° standard in Egypt is about 5° earlier than the time of true Dawn and found that the light that appears at −19° is a pseudo-dawn that does not meet the criteria of horizontal transverse light.[9] The

[6]Marataon Ritonga, "Problematika Syafak Dan Fajar Dalam Menentukan Waktu Salat Isyak Dan Subuh," *Al-Marshad: Jurnal Astronomi Islam Dan Ilmu-Ilmu Berkaitan* 7, no. 2 (2021): 169–82.

[7]Moh. Afif Amrulloh, "PENENTUAN AWAL WAKTU SHALAT SUBUH MENURUT KEMENTERIAN AGAMA DAN ALIRAN SALAFI," *JURISDICTIE*, 2012, https://doi.org/10.18860/j.v0i0.2165.

[8]B A Marzouk et al., "Sun Vertical Depressions and Their Effects on the Morning Twilight Phases in Egypt BT - Proceedings of the 14th Arabic Conference of the Arab Union for Astronomy and Space Sciences," ed. Hamid M K Al Naimiy, Hussein M Elmehdi, and Ihsan A Shehadi (Singapore: Springer Nature Singapore, 2025), 178–209.

[9]Abdel-Hadi Yasser Abdel-Fattah and Amir Hussein Hassan, "The Effect of Sun Elevation on the Twilight Stages in Malaysia," *International*

phenomenon of false Dawn occurs when the sun is between -19° and -15°. This type of lighting is characterized by its vertical rise and disappearance within 4°, after which the true Dawn begins to appear. He explained that this light is not a sign of Dawn because it has not yet spread horizontally across the eastern horizon. According to Hassan and others, unfortunately, most countries mistakenly consider the first appearance of light from the east to be true Dawn, which is a grave error. What they are using is a false dawn, not a true dawn.

In this context, this study aims to examine the influence of the Sun's vertical depth on the appearance of morning dawn light in Medan City, using naked-eye observation. Observations were made to record the time when Dawn first became visually visible and to analyze the factors that affect its appearance in urban environments. Dawn is an astronomical phenomenon marking the beginning of the Fajr prayer time.[10] In religious practice, what is meant is the Dawn of shādiq, in the form of horizontal, longitudinal light on the eastern horizon, unlike the kādzib Dawn, which is vertical and soon disappears. However, the shādiq Dawn visibility is influenced by local conditions (light pollution, aerosols/humidity, clouds, topography), so there is often a difference between hisab results and visual/photometric observations. This difference has implications for fiqh, especially the certainty of the beginning of Fajr .[11]

Officially, the Ministry of Religion (Kemenag) of the Republic of Indonesia uses the criterion of the Sun −20° for the beginning of Fajr, and has several times affirmed its suitability in

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Journal of Astronomy and Astrophysics 12, no. 1 (2022), https://doi.org/doi.org/10.4236/ijaa.2022.121002.

[10]Alhan Devina Kharida Ismail, Ruslandi, "Analisis Tingkat Kecerahan Langit Malam Terhadap Visibilitas Hilal Menggunakan Sky Quality Meter Di Observatorium Malikussaleh Lhokseumawe," *Astroislamica: Journal of Islamic Astronomy* 4, no. 1 (2025): 25–39, https://doi.org/10.47766/astroislamica.v4i1.3374.

[11]Unggul Suryo Ardi, "Problematika Awal Waktu Shubuh Antara Fiqih Dan Astronomi," *AL - AFAQ : Jurnal Ilmu Falak Dan Astronomi* 2, no. 2 (2021): 87–102, https://doi.org/10.20414/afaq.v2i2.2921.

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terms of fiqh and science.[12] On the other hand, since 2021, Muhammadiyah has set −18°.[13] Based on a series of internal empirical research, it was concluded that at −20° the light of Dawn of Shādiq is not yet apparent, so the −20° schedule is judged to be about 8 minutes early. These differences have practical implications in the field, affecting perceptions of "dawn is too early" and driving the need for a national calibration based on multisite observations with methodological standards (cameras, photometry, SQM, light pollution control).

METHOD

This study used direct visual observation with the naked eye and the Sky Quality Meter that pointed at the East Horizon to record Dawn's appearance in Medan City, Indonesia. Observations were conducted over multiple sessions from 2022 to 2024, totalling 15 observation days across varying sky conditions at the UMSU Campus. The location is summarized in Table 1.

Table 1. Medan City Coordinate and Bortle Scales

Location	Location type	The Average of Sun Do Visual & SQM
Medan 3°34'54.93"N, 98°43'18.01"E	Urban 8,4 Bortle Scale	14.5°

The early-dawn visibility data were then compared across various locations based on NRIAG research. The observation begins about 60 minutes before the Fajr prayer time listed in the

[12]Karina Aulia Purwanti, *Awal Waktu Salat Subuh Perspektif Kementrian Agama RI*, vol. 1, 2022.

[13]Pimpinan Pusat Muhammadiyah, "Keputusan Pimpinan Pusat Muhammadiyah Nomor 734/KEP/1.0/B/2021 Tentang Tanfidz Keputusan Musyawarah Nasional XXXI Tarjih Muhammadiyah Tentang Kriteria Awal Waktu Subuh," Tanfidz Munas Tarjih, 2021.

official calendar of the Ministry of Religion of the Republic of Indonesia. It continues for 30 minutes after that time. Observers record the time when the light of Dawn was first visually visible on the eastern horizon. To determine the sun's vertical altitude at that time, astronomical software such as Stellarium is used to calculate the sun's position below the horizon, given the observer's geographical coordinates and the time of observation. In addition, weather conditions and light pollution levels around the observation site were recorded to analyze their effects on the appearance of Dawn. The collected data were then analyzed to determine the range of the Sun's depression angle at first visual visibility and to evaluate the factors influencing the difference between the theoretical and observed dawn times.

RESULTS AND DISCUSSIONS

Periodic visual observations of the appearance of Dawn in Medan, conducted from 2022 to 2024, show a consistent pattern in the initial visibility of true dawn light (fajr shādiq). Based on field observations at several observation points, including the UMSU Campus, the dawn light was first observed when the Sun was at a depression angle of −14° to −12° below the eastern horizon. Medan is a large tropical urban city situated at low latitude, characterized by a humid equatorial climate, high annual temperatures (average 26–32 °C), high relative humidity (typically >70%), and frequent thin cloud cover in the early morning hours. As a metropolitan area, Medan experiences significant light pollution, with measured sky brightness values generally ranging from 16 to 18 mag/arcsec², thereby reducing twilight sky contrast. These climatic and environmental factors were recorded during each observation session, as they directly influence the visual detection of true Dawn. In its early stages, the light appears as a thin, horizontal, greyish-white band that widens and intensifies until it fills the eastern sky. This phenomenon marks the transition from night to early morning and is an astronomical marker for the entry of dawn time in shar'i.

During the observation period as shown in table 2, the time difference between the visual Dawn and the official Fajr

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schedule of the Ministry of Religion of the Republic of Indonesia ranged from 2° to 3°. This difference was consistent across almost all observation sessions, although daily weather conditions caused minor variations.

Table 2. Fajr Visibility from Observation

Cloudless				Cloudy			
Date, yyyy-mm-day	hh:mm	Sun vertical depression	Light magnitude (m, mag. $arcs^{-2}$)	Date, yyyy-mm-day	hh:mm	Sun vertical depression	Light magnitude (m, mag. $arcs^{-2}$)
2022-12-10	05:28	12° 45′	16.15	2022-07-28	05:40	10° 55′	17.130
2023-02-21	05:35	16° 15′	18.376	2023-03-02	05:55	10° 53′	17.206
2023-06-16	05:25	12° 21′	17.222	2023-09-21	05:38	09° 58′	17.414
2024-04-27	05:24	13° 09′	17.387	2024-01-25	05:48	12° 36′	17.008
2024-06-06	05:20	14° 06′	17.309	2024-02-05	05:57	11° 00′	17.573
2024-08-03	05:36	11° 48′	18.678	2024-07-30	05:37	12° 01′	17.366
2024-08-28	05:27	13° 47′	17.800	2024-09-27	05:33	10° 47′	17.565
2024-10-15	05:19	13° 16′	19.720	2024-12-21	05:41	11° 01′	17.728
Mean	05:26	13° 29′	17.830		05:43	11° 8′	17.373
SD	0.004453	1.3599	1.085618		0.006076		0.246338

Urban light pollution is the leading cause of delayed visual perception, as the intensity of artificial light from streetlights, vehicles, and commercial areas around the observation site reduces the contrast of the eastern sky. In addition, the thin cloud layer and high atmospheric humidity in the early morning hours further scatter light, slowing the visual detection of true dawn light. In some sessions, the new Dawn appears to be about 3°–4° shallower than the theoretical value of −18°, suggesting that urban tropical sky conditions produce a

dawn depression that is smaller than the standard calendar value. SQM reading on Dawn in Medan city is also primarily visible around 12-14 degrees, as shown in Figure 1.

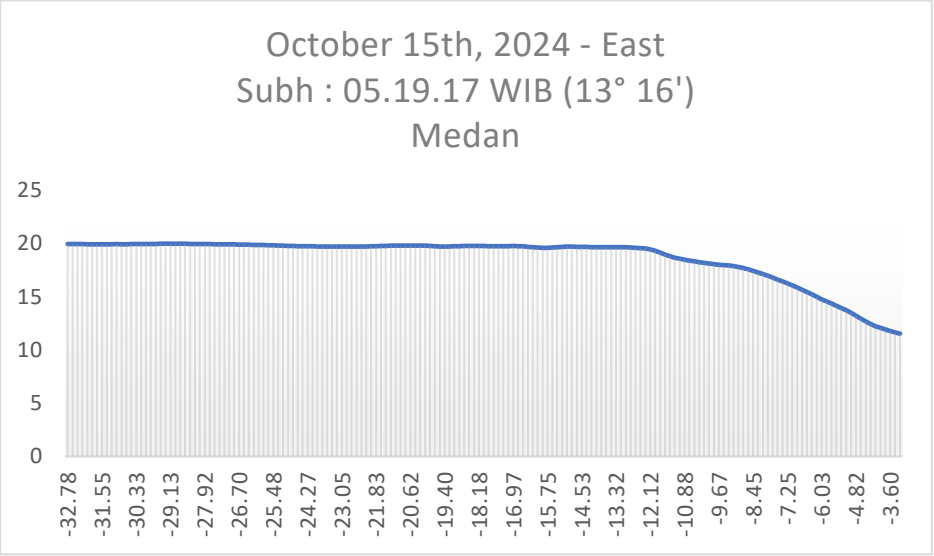

Figure 1. SQM Reading on Fajr Time in Oct 15, 2024 from OIF UMSU

These results reinforce findings from previous studies in Indonesia, which show a similar tendency: the Fajr schedule with a standard of −20° yields a time earlier than the actual observations. Light pollution, urban topography, and tropical atmospheric conditions significantly reduce the visual contrast of Dawn, allowing new horizontal light to be identified as the Sun rises closer to the horizon. In general, the results of Medan observations show dawn characteristics similar to those in other urban areas at low latitudes, where true dawn depressions tend to be in the range −14° ± 1°, whereas locations with dark or rural skies can reach −16° or more.

This comparison of results is consistent with research by Semeida and Hassan (2018), who conducted 38 naked-eye observations in Wadi El-Natron, Egypt.[14] They found that true

[14]A.H. Hassan et al., "Naked Eye Observations for Morning Twilight at Different Sites in Egypt," *NRIAG Journal of Astronomy and Geophysics* 3, no. 1 (2014): 23–26, https://doi.org/10.1016/j.nrjag.2014.02.002.

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Dawn consistently occurs when the Sun is at an angle of −14.57° (average), with a range of −15.1° to −12.5°, while pseudo-dawn occurs earlier, at about −19.7° to −14.6°. The results show that the −19.5° Fajr time criterion used in Egypt is about 5° too early relative to the observed true Dawn.

The results of these observations are also consistent with those of Abdel-Hadi et al. (2022), who conducted dawn observations in the Fayum Desert (a high-visibility region), about 100 km southwest of Cairo. Observations were made using a combination of the naked eye method and a high-resolution CCD camera to distinguish between true Dawn and pseudo-dawn. The results show that true Dawn occurs when the Sun is at a depression angle of −14.7° ± 0.5°, while pseudo-Dawn occurs earlier at −18.6° ± 0.8°, with a time difference of about 5°. The study at Fayum confirms that Egypt's official Fajr schedule (−19.5°) occurs earlier than the visually observed true Dawn.[15]

Another studies on the phenomenon of true Dawn, which is a crucial component of morning twilight for both Islamic ritual observance and astronomical observations, emphasize the central role of naked-eye observations as a fundamental reference for assessing light magnitude during twilight. Research conducted across several desert locations with similar latitudes but differing climatic conditions, including Riyadh (Saudi Arabia), 15th May City (Egypt), Mauritania, and Aswan, demonstrated that the onset of true Dawn varies with atmospheric and visibility conditions, generally occurring between solar depression angles (Do) of about 12.7° and 14.9°. In Riyadh, true Dawn was observed to spread gradually from Do ≈ 14.6°, expanding horizontally up to an azimuth width of approximately 80°, with light intensity exhibiting a color gradation of red > green > blue; false Dawn appeared earlier at Do ≈ 18.6° ± 0.85, while true Dawn occurred at Do ≈ 14.6° ± 0.3.

[15]M. G. Rashed et al., "DETERMINATION OF THE TRUE DAWN BY SEVERAL DIFFERENT WAYS AT FAYUM IN," *International Journal of Mechanical Engineering and Technology* 13, no. 10 (2022): 8–24, https://doi.org/https://doi.org/10.17605/OSF.IO/9K3MJ.

In Egypt, observations at 15th May City indicated a later onset of true Dawn at Do ≈ 12.7° ± 0.81, influenced by reduced horizontal visibility due to urban wind patterns. In contrast, observations in two adjacent desert sites in Mauritania showed true Dawn at Do ≈ 14.9° ± 0.61. Under optimal atmospheric conditions with excellent visibility, studies consistently indicate that the true dawn onset across desert environments converges on Do ≈ 14.4°.[16]

These results are in line with those of Putraga et al. (2022), who used DSLR cameras and moving-average methods to analyze the time of Dawn at several locations in Indonesia. They found that the angle of Dawn shādiq ranged from 14° to 13°, and that there was a time difference of up to 4° from the Ministry of Religious Affairs' official schedule, depending on the conditions of the sky and surrounding light.[17] Their research reinforces the importance of observational approaches in verifying dawn time.

Another study by Hassan (2022) in Tubruq, Libya, using visual methods, also showed that true Dawn occurs when the Sun is between 14° and 12° below the horizon.[18] Hassan compared the results of observations at locations with different levels of light pollution. He found that the brighter the sky conditions (the lower the pollution), the more easily recognizable true Dawn is at a consistent depression angle of −14° to −13°. In contrast, in regions with intense artificial light or high humidity, true Dawn appears later, and the time difference relative to the official schedule is even greater. These results confirm that local environmental factors, such as light pollution, aerosols, and atmospheric conditions, significantly affect the initial visual

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[16]Ayman I Taha et al., "Observation of the True Dawn for Three Different Countries in the Arab Region," *Emirati Journal of Space and Astronomy Sciences* 3, no. 1 (2025): 4–17, https://doi.org/10.54878/e3q5jd54.

[17]Hariyadi Putraga et al., "Penentuan Waktu Malam Menggunakan Sky Quality Meter Dengan Pendekatan Moving Average," *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika* 8, no. 2 (2022): 313, https://doi.org/10.31764/orbita.v8i2.11363.

[18]Amir Hussein Hassan et al., "NAKED EYE ESTIMATES OF MORNING PRAYER AT TUBRUQ OF LIBYA," *Al-Hilal: Journal of Islamic Astronomy* 3, no. 2 (2021), https://doi.org/10.21580/al-hilal.2021.3.2.8625.

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perception of Dawn. The similarity of the dawn depression angle range between observations in Medan and Libya shows that, despite the different locations, the visual approach yields relatively similar conclusions under ideal conditions.

In addition, these results are consistent with the results of a scientific study by Putraga (2018) in North Sumatra, which stated that in the context of direct observation, Dawn does not always appear when the Sun is at -20° to -18°,[19] as used in the national prayer schedule. In fact, Dawn is often observed only at an angle of -14°, consistent with observations in Medan. Thus, this field data reinforces the need to review the time of Dawn listed in the calendar locally, especially in urban areas such as Medan. The visual observation approach provides relevant, contextual results and can be combined with measurement instruments to yield more objective, scientific results.

In Indonesia (Depok 6° 26′ 53.73″ S and 106° 48′8.01″ E, the southern suburb of approximately 25 km from Jakarta), the true Dawn was found to begin at Do=14°±0.6 observed by the SQM instruments.[20] The Sky Quality Meter (SQM) was used in four regions in Malaysia to measure night-time brightness at pseudo-dawn and true Dawn. The measurements were taken when the device was pointed eastward at a 5-degree angle above the horizon throughout the monitoring period. The altitude of the sun (a) and the illuminance of night sky in magnitude (m) (mag./arcsec2) for the beginning of the true Dawn were found to be at a= −14.19˚ ± 0.52˚ (for high confidence a= −14.71˚) and m=21.22m ±0.25 respectively, the begin of the pseudo Dawn were found to be at a= −18.62˚ ± 0.82˚ and m=22.17m±0.104

[19]Hariyadi Putraga, "Tinjauan Saintifik Awal Waktu Subuh" 1, no. 1 (2018): 34–43.

[20]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 (January 2020): 238–44, https://doi.org/10.1080/20909977.2020.1738106.

respectively.[21] The full hierarchical shape of the pseudo Dawn does not occur regularly. The difference in the illuminance of light magnitude (*m*) between the true Dawn and the whole night was found to be 0.83m (Abdel-Hadi and Hassan, 2022, I and II).

Studies conducted by Abdel-Hadi and Hassan in Malaysia (2022) found that true Dawn occurs in a solar depression around −14.19° ± 0.52˚, while pseudo-dawn occurs at −18.62°± 0.82.[22] Other results in Egypt showed true dawn consistency in the −14° to −15° range, both by naked-eye observation and with CCD and SQM instruments.[23] Meanwhile, observations by OIF UMSU in Medan show that dawn light is first observed when the Sun is at a depression of −14° to −12°.[24] This value falls within a range almost identical to the NRIAG results in Egypt and Malaysia, though with a slight shift toward a shallower limit due to high tropical urban light pollution.

The similarity of these results confirms a strong correlation between the OIF UMSU and NRIAG research, despite the different geographical settings (tropical urban in Medan vs. coastal and desert in Egypt). The slight differences that arise are more due to local factors, especially the level of sky brightness. Research on sky brightness in North Sumatra shows that the SQM value in Medan is only around 16-18 mpsas, much lower than the west coast of Sumatra, which reaches 21.87 mpsas. It shows that urban locations make Dawn look slower than locations with minimal light pollution. His observations showed that most locations at middle and low latitudes produced true dawn depression values of −15° ± 1°, consistent with

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[21]M.M. Hussien et al., "The Effect of the Total Energy of the Stars and the Presence of the Moon Above the Horizon on the Onset of True Dusk and True Dawn," *Journal of Information Systems Engineering and Management* 10, no. 50 (2025): 840–52.

[22]Abdel-Fattah and Hassan, "The Effect of Sun Elevation on the Twilight Stages in Malaysia."

[23]Hassan et al., "Naked Eye Observations for Morning Twilight at Different Sites in Egypt."

[24]Arwin Juli Rakhmadi, Hasrian Rudi Setiawan, and Abu Yazid Raisal, "Pengukuran Tingkat Polusi Cahaya Dan Awal Waktu Subuh Di OIF UMSU Dengan Menggunakan Sky Quality Meter," *Titian Ilmu: Jurnal Ilmiah Multi Sciences* 12, no. 2 (2020), https://doi.org/10.30599/jti.v12i2.667.

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observations in Indonesia. Thus, the problem of the time of Dawn being too fast is a global phenomenon, not limited to any one country

CONCLUSION

Based on the results of visual observations in the city of Medan, true dawn light begins to appear when the Sun is at a depth between −14° to −12° below the horizon, with an average appearance of about 5° later than the official Fajr schedule of the Ministry of Religion of the Republic of Indonesia which uses the −20° standard. These results show that tropical urban sky conditions, such as those in Medan, with a brightness level of only 17–18 mpsas, delay the perception of dawn light compared to areas with darker skies. A comparison with the Egyptian NRIAG study showed that the true dawn depression range of −15° to −14° is suitable under high-visibility conditions. A local-observation approach and continuous photometric measurements, especially in urban areas, are needed to produce a more accurate, contextually consistent, and consistent dawn-time standard in accordance with Islamic astronomical principles.

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