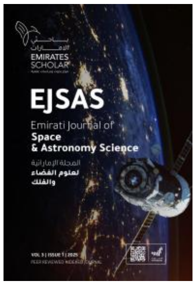

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Observation of the true dawn for three different countries in the Arab region

Ayman I. Taha[1], Zaki A. Al- Mostafa[2], S. F. Ragheb[3], A. H. Hassan[4], M.M. Hussien[5]
ayman_ismail1@yahoo.com, zalmostafa@kacst.edu.sa[2], ahhassan210@gmail.com[3], ahhassn210@yahoo.com[4], magdamoheb@yahoo.com[5]
National Research Institute of Astronomy and Geophysics (NRIAG), Cairo, Egypt[1,3,4,5]
King Abdulaziz City for Science & Technology, National Center for Astronomy and Navigations, KSA[2]

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ABSTRACT

The study of the phenomenon of true dawn, a critical component of morning twilight, has great importance for Muslims (who constitute nearly a quarter of the world's population) and for astronomy in general, especially in viewing celestial bodies during the twilight period. Observation with the naked eye is of utmost importance in monitoring celestial phenomena and bodies during the hours of night and twilight, and it also serves as a basic reference for the light magnitude calculation. This research involved naked-eye observations of true dawn across three distinct desert locations with varying climates but similar latitudes. One location also included concurrent camera observations. In Riyadh (KSA), the true dawn was observed to progressively spread and expand from the point of solar depression (Do) of 14.6 degrees (where Do represents the negative solar altitude), with the horizontal azimuth widening until the dawn light reaches the range of WAZ=80˚. The color gradation intensity of light during true dawn is red > green > blue, the false dawn is at Do = 18.58°±0.85, while the true dawn is at Do = 14.88° (14.58°±0.3). The false dawn was observed at Do =18.58˚ ± 0.85 and the true dawn occurred at Do =14.58˚± 0.3. On the 15th of May City, Egypt, the true dawn was observed at a solar depression (Do) of 12.69° (11.88° ± 0.81°). This observation was influenced by reduced horizontal visibility due to wind direction from the city of Helwan. Observations conducted in two adjacent desert locations in Mauritania revealed a true dawn onset at Do = 14.85° (14.24° ± 0.61°). Under optimal conditions, characterized by excellent visibility (full moonlight and phase of the moon around, f ≈ 1), the true dawn onset in locations such as Riyadh, Mauritania, and Aswan, Egypt, was observed to occur at approximately Do ≈ 14.4°.

1. Introduction

Naked-eye observations serve as the fundamental reference for validating and comparing measurements obtained from any other instrument. The human visual system exhibits unparalleled sensitivity to light and color, capable of distinguishing an estimated 7-10 million distinct hues – a capacity yet to be replicated by any artificial device [1]. In astronomy, the apparent magnitude of celestial objects is inherently linked to human visual perception. This has spurred extensive research into the human eye's color discrimination capabilities and light thresholds across different spectral ranges.

Lunar twilight, which begins when the lunar disk approaches the horizon, entirely resembles solar twilight but is very much weaker. The brightness of lunar illumination fluctuates, depending on the age of the moon, between 10^{-9} Lux (at new moon) and $2x10^{-6}$ Lux (at full moon) of the brightness of solar illumination for corresponding positions of the bodies on the celestial sphere. Thus the level of illumination for a high full moon corresponds approximately to the middle of solar nautical twilight, while the end of lunar astronomical twilight (again at full moon) almost coincides with moonset [2]. Nevertheless, the contribution of the full moon to the sky brightness is best taken into account until the moon has dropped to D_o = 5 -7° below the horizon [3].

Hassan et al. [4] demonstrated a strong correlation between photoelectric measurements and naked-eye observations of morning twilight (specifically, true dawn) across four regions in Egypt. Extensive research has been conducted on the phenomena of true dawn and false dawn. It is well-established that the visual detection of faint celestial phenomena, such as the zodiacal light, false dawn, and the onset of true dawn, is critically dependent upon the human eye's contrast sensitivity during the evening or morning twilight [5-6].

The human visual system exhibits remarkable adaptability to varying light intensities. While the iris, through pupil dilation and constriction, plays a crucial role in light regulation, its dynamic range (approximately fourfold) is insufficient to account for the human eye's ability to function across a 1:1,000,000 range of luminance. Retinal adaptation, a complex physiological process, plays a pivotal role in compensating for this limitation. The human eye exhibits a logarithmic response to light intensity, meaning that the perceived change in brightness is less pronounced for larger increases in actual light intensity. The minimum light energy required to elicit a visual response in the human eye must be at least 10^{-6} Watts, corresponding to an influx of approximately 250 photons per second. However, a significant portion of these photons are lost before reaching the retina. Approximately 2% of incident light is reflected at the corneal surface. For light with a wavelength of 500 nm, approximately 50% of the remaining photons are absorbed or scattered by ocular media before reaching the retina. Quantum efficiency, defined as the ratio of photons absorbed by rhodopsin (a visual pigment) that triggers a neural response to the total number of photons incident on the cornea, further diminishes the effective photon count. It is important to note that this description focuses on the physiological mechanisms of light perception. The psychological aspects of visual perception, such as contrast sensitivity and color perception, also significantly influence the human eye's ability to detect and interpret faint celestial phenomena.

The study of twilight phenomena, encompassing both false dawn and true dawn, holds significant importance across various scientific disciplines. These phenomena: (a) Inform lunar calendar determinations: Accurate observation of the new moon, influenced by the backdrop of evening and morning twilight, is crucial for establishing the lunar calendar, (b) Contribution to astrophysical research: The total energy of stars and zodiacal light and the effect of twilight on them must be considered, as twilight light represents the gradual transition between complete night and the beginning of day [7-9].

A numerical analysis was conducted to assess the penetration of solar radiation within the 100-600 nm wavelength range into the lower atmosphere (<100 km) during the pre-sunrise period. The results of these studies have demonstrated the relative importance of absorption by molecular oxygen and ozone, and Rayleigh scattering processes in attenuating the propagation of solar radiation during this critical phase [10].

During the winter of 1908 in Aswan, Egypt, camera-based observations of morning and evening twilight were conducted. The results indicated that the initial appearance of faint light (false dawn) occurred at D_o = 17.35°, while the first discernible color differentiation, marking the onset of true dawn, was observed at D_o=14.25°. Conversely, the disappearance of dusk during evening twilight was observed at D_o = 14.9° [11].

Rozenberg (1966) reported that the emergence of the intrinsic glow of the upper atmosphere, concurrent with the appearance of starlight, commences when the solar depression (D_o) reaches 10-15°. This marks the gradual transition towards night-sky conditions.

Furthermore, Rozenberg observed that the transition to complete night occurs when the D_o reaches 17-19° [3].

In Sana'a, Yemen (Lat. 15.4° N, Long. 44.2° E, Elev. 2200m), Sultan conducted observations of morning twilight during the autumn of 2003. Following a period of heavy rainfall, exceptional observation conditions prevailed from November 23rd to 28th, characterized by clear skies and dry, sunny days. These observations, conducted with the naked eye, revealed the following: False dawn; the onset of astronomical twilight, marked by the initial faint glow, was observed at a solar depression (D_o) of 18.95°. Developing twilight; A discernible color divergence in the twilight sky commenced at D_o = 13.2°. True dawn; the onset of nautical twilight, characterized by a more pronounced brightening of the sky, was observed at D_o = 12° [12].

Twilight sky brightness in the UBVRI bands was estimated from over 2000 archival FORS1 images, encompassing both flat-field calibrations and standard star observations acquired during twilight conditions (4° ≤ D_o ≤ 22°). Twilight observations have emerged as valuable tools for characterizing atmospheric structure, with significant implications for the evaluation of astronomical sites. Recent interest in this field has been spurred by the assessment of Dome C, Antarctica, as a potential astronomical site, which has included dedicated twilight brightness measurements. A key finding of this work was the identification of the onset of true dawn at D_o=14.8°. Furthermore, a critical transition point was observed, where the spectral signature of reflected Earthshine transitions from a blue-dominated spectrum (dominated by Rayleigh scattering of solar radiation) to a pseudo-continuum dominated by night sky emission at approximately D_o = 15° [13].

Many studies conducted between 2008 and 2019 across various locations in Egypt, including Bahria, Kottamia, Matrouh, Aswan, Sinai, Assiut, and Wadi Al Natron, have investigated the onset of true and false dawn. These studies, encompassing both photoelectric measurements and naked-eye observations, have consistently demonstrated that the solar depression (D_o) at the commencement of true dawn typically ranges between 13.5° and 15°, while the onset of false dawn occurs is at D_o between 15.5° and 18.5°. These observations encompass diverse environmental backgrounds, including desert, coastal, and agricultural landscapes [8] [14-18].

In Tubruq, Libya (Lat. 32°05' N, Long. 23°59' E, Elev. 40m), observations conducted during 2007-2008, characterized by Mediterranean Sea conditions, revealed the onset of true dawn is at D_o =13.48°. Subsequent observations carried out between 2009 and 2013, under desert conditions, demonstrated a shift in the onset of true dawn to D_o = 14.7° [19-20].

A study conducted in Hail, KSA (Lat. 27°31' N, Long.41°42' E, Elev.1015m), and across multiple deep desert locations investigated the onset of true dawn. True dawn was characterized by the emergence of a visually perceptible, steadily intensifying light. Naked-eye observations consistently indicated the onset of true dawn is at D_o within the range of 14.66° to 14.8° [21].

A study conducted in Depok, Indonesia (Lat. 6°27' S, Long.106°48' E, Elev.50-140m) employed SQM instruments to analyze 26 cloudless morning twilight events. The results of this analysis indicated that the onset of true dawn occurred at D_o= 14° ± 0.6°. All measurements were acquired with the sensor directed towards the zenith [22].

In Malaysia, a series of observations were conducted at five locations to investigate the brightness of the night sky during morning twilight. Utilizing SQM instruments directed eastward at an elevation of five degrees above the horizon, the onset of true dawn was determined to occur at D_o= 14.19° ± 0.52 (with a high-confidence value of 14.71°), corresponding to a sky brightness of 21.22^m ± 0.25 mag./arcsec² (m, magnitudes). The onset of pseudo dawn was observed at D_o =18.62° ± 0.82 and a sky brightness of 22.17^m ± 0.104. The hierarchical structure of the pseudo-dawn was not consistently observed. The difference in sky brightness between true dawn and full night was found to be 0.83 magnitudes relative to the background sky brightness [23].

In Fayum, Egypt (Lat.29°17' N, Long.30°03' E, Elev.50m), observations of morning twilight were conducted during 2018-2019 under excellent seeing conditions. Utilizing naked-eye observations and SQM measurements, the onset of true dawn was determined to occur within the range of D_o = 14° to 14.8°. Furthermore, it was observed that the illuminance of night sky radiation became equal in both vertical and eastward directions at the onset of nautical twilight at D_o = 12° [24].

Table 1 presents a compilation of key findings from previous research on the solar depression angle (D_o) at the onset of true dawn. The table includes data from various locations, specifying the year of publication, the observation method employed (Camera, Photoelectric measurements (P.E), Naked eye (N.E), Sky Quality Meter (SQM), CCD camera), and the observation direction (East or Vertical).

Table 1 the most important research for true dawn of places observation for the Publication year, the tools of observations as; Cameras, P.E, N.E, SQM, CCD, and observing direction as the east or vertical and sun vertical depression, Do (degree),

Place	Publication Year	Tool	Direction	D_o (degree)	Reference
Egypt, Aswan	1909	Camera	East	14.25	[11]
Yemen, Sana'a	2004	Camera, N.E	East	12˚	[12]
KSA, Hail	2018	N.E	East	14.66 -14.8	[21]
Libya, Tubruq (2 researches)	2007-2008 and 2009-2013	N.E	East	13.5-14.7	[19-20]
Egypt (9 researches)	2008-2019	N.E and P.E	East	13.5-14.7	[4][8][14-18]
Indonesia, Depok	2020	SQM	Vertical	14±0.6	[22]
Malaysia (5 regions)	2021	SQM	East	14.71	[23]
Indonesia, Malaysia, USA, Egypt, Turkey	2021	SQM	East and Vertical	12-13	[24]
Egypt, Fayum	2022	N.E and SQM	East	14- 14.8	[25]
Egypt (6 regions)	2024	Camera, N.E, SQM, and CCD.	East	14-14.8	[26]

This study aims to investigate the characteristics of true and false dawn in Riyadh, Saudi Arabia, and determine the onset of true dawn in two locations in Mauritania (Mur.1 and Mur.2) and 15th of May City, all situated in desert regions. Additionally, the study will explore the influence of moonlight on the observed onset of true dawn.

2.Site observations

All morning twilight observations in this research were taken horizontally towards the east and at a height (h) above the horizon not exceeding, h≤5˚.

Table 2 represents the locations of observation, Lat. (N), Long. (E and W), Elev., NL, numbers of observation data (No) and the tools of observation (tool) for morning twilight days.

Table 2 the coordinates of the site, Lat. (N), Long. (E and W), Elev., tools of observation (Tool) numbers of observation data (No) and observation period.

Location	*Lat*. (N)	*Long*. (E & W)	*Elev*.(m)	Tool	*No*.	Observation period
SKA, Riyadh	25: 46	47:12 E	540	N.E &Camera	13	Feb.2004- March 2005
Egypt, 15th May city	29: 52	31: 21E	87	N.E	41	Nov.2014- March 2015
Mauritania, Mur. 1	20:51	14:23 W	170	N.E	5	Jan, 2024
Mauritania, Mur. 2	20:15	15:17 W	91	N.E	5	Jan, 2024

2.1 Riyadh, KSA

Naked-eye and camera-based observations were conducted in Riyadh, KSA, during the 13th morning observation period. The observation site is located in a deep desert area northeast of the capital.

Table 3 provides a comprehensive study conducted in Riyadh, KSA, from February 2004 to March 2005, investigated the impact of various atmospheric parameters on morning twilight observations. These parameters included air temperature (T, °C), relative humidity (RH, %), atmospheric pressure (mb), wind speed (WS, m/s), wind direction, and visibility (rated on a scale of 1-4), which were recorded by observers during real-time observations [27].

Table 3 the important factors affecting morning twilight measured in KSA (Riyadh, Feb.2004-March 2005) as; T (°C), RH (%), atmospheric pressure (mb), WS (m/s), wind direction beside the visibility (1-4), were degrees of the visibility are divided into: the visibility is excellent (1), light dust (2), partly cloudy (3) and light zipper (4), where the highest transparency gives the number one.

Date	T (°C)	RH (%)	Pressure (mb)	WS (m/s)	Visibility	Wind direction
27-2-2004	9	23	949	1.03	1	ENE
2-4-2004	20	24	944	3.08	1	SSE
12-5-2005	26	12	934	3.60	1-2	W
28-5-2004	27	9	936	3.60	1-2	W
24-6-2004	29	10	935	2.06	1-2	E
23-7-2004	23	9	935	1.54	1-2	ESE
27-8-2004	27	12	936	2.06	1	NNE
24-9-2004	23	11	943	2.06	1	N
17-10-2004	21	13	947	1.03	1	E
26-11-2004	10	30	947	4.11	3	S
28-12-2004	7	38	949	5.14	1	WNW
7-2-2005	7	34	944	3.6	4	NW
3-3-2005	10	54	944	2.06	1	ES

2.2 Mauritania

"Naked-eye observations were conducted in Mauritania during the 10th morning observation period. The observation sites were located near the cities of Jeneifisa (Mur.1) and Jorf (Mur.2) in a deep desert environment."

2.3 15th of May City, Egypt

Naked-eye observations were conducted on the 15th of May City, Egypt, for 41 mornings. The observation site was located to the east of the city, free from significant human activity or light pollution. While the city is situated within 10 kilometers of the Helwan industrial complex (comprising cement and steel factories), wind direction data indicate that these sources contribute only 8.49% of the overall wind direction, primarily from the northwest (NW) and southwest (SW) sectors. Tables 4 and 5 present the monthly mean values of key atmospheric parameters at this location.

Table 4 presents a summary of key climatic parameters observed on the 15th of May City, including monthly mean values of air temperature (T, °C), relative humidity (R.H, %), number of rainy days (RD), and average length of the night (AN, hours), calculated as AN = (24 - SH), where SH represents the duration of daylight. This data provides valuable context for the analysis of morning twilight observations conducted at this location [28].

Table 4 shows the monthly mean of basic climatic elements of the 15th May city as: T (C˚), R.H (%), Rainy days (RD, d), AN (h) = (24-SH).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T (°C)	13.8	14.9	17.7	21.5	25.5	27.8	28.7	28.6	26.4	24.4	20.3	15.6
R.H (%)	56	54	47	41	35	34	37	42	44	47	52	54
RD (d)	0	1	1	0	0	0	0	0	0	0	0	0
AN (h)	15.9	16	15	13.8	12.8	12	11.7	12.2	12.8	13.5	14.2	15.2

Table 5 presents the distribution of wind directions and their corresponding percentages within the Helwan region, which is located within 10 km of 15th of May City. As neighboring regions can influence atmospheric transparency, wind direction is considered a crucial factor, alongside other climatic elements.

Table 5 the distribution of wind directions and their percentage over Helwan region in general, and thus the neighboring 15th May City, which is not more than 10th Km away.

Wind direction	NE	N	E	NW	SW	S
Percentage (%)	38.61	34.75	15.44	5.4	3.09	2.07

3. Methodology

Observations across all locations were primarily conducted using the naked eye (N.E.). In Riyadh, observations were supplemented by data acquired using a Nikon D70 camera (F/3.5, 18 mm focal length). Image analysis was performed using Maxima DL Version 5.47.0 software to extract red (600-700 nm), green (500-600 nm), and blue (400-500 nm) color components, denoted as R, G, and B, respectively. Observations were conducted by four independent groups, each consisting of two observers. A substantial portion of the data for Riyadh was obtained from a research project conducted by the Institute of Astronomy and Geophysics in King Abdulaziz City, KSA [27]. Solar and lunar coordinates were computed using in-house programs [4, 14-16] and subsequently verified by Monzur [30]. Color indices were calculated according to the following equations: B-G = -2.5 Log (IB/IG), G-R = -2.5 Log (IG/IR), and B-R = -2.5 Log (IB/IR) [3] [17].

4. Results and analysis

The influence of the moon on evening and morning twilight exhibits four distinct phases. Solar and lunar elevations for each measurement were obtained from the U.S. Naval Observatory's Astronomical Applications Department website [www.aa.usno.navy.mil]. The lunar phase angle ϕ (0° for a full moon; 180° for a new moon; 90˚ for first and last quarter) was also taken from the same website and used to approximate the fraction of the lunar disk illuminated f via., $f = 0.5 (\cos \phi + 1)$, as; new moon (NM, ϕ =180˚ and f = 0), first quarter and last quarter (FQ, LQ: ϕ =90˚, f= 0.5), full moon (FM, ϕ = 0˚, f= 1) [31-32].

4.1 For Riyadh (KSA)

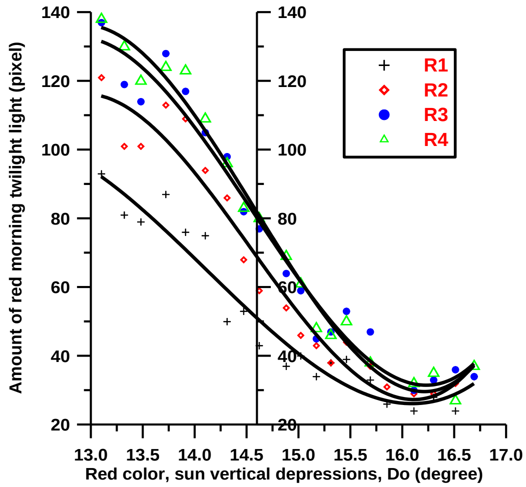
Table 6 presents the temporal progression of morning light observed in Riyadh, KSA, on March 3, 2005. The table illustrates the relationship between the solar depression angle (Do) and the corresponding horizontal spread (WAz) of the dawn light. Observations revealed an initial horizontal spread of 20° at a solar depression of 15.5°. As the sun descended below the horizon, the horizontal spread gradually increased, reaching 70° at a solar depression of 14.8°. Subsequently, the spread stabilized at 80° with a solar depression of 14.6°. This final stage was characterized by the emergence of a distinct, clearly defined horizontal white line, marking the unambiguous onset of dawn

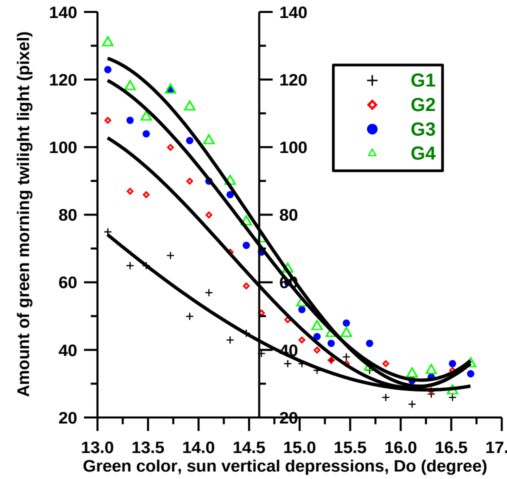
Table 6 displays the light azimuth as the dawn light progresses and expands (WAZ, degree) of light with sun vertical depressions (Do, degree).

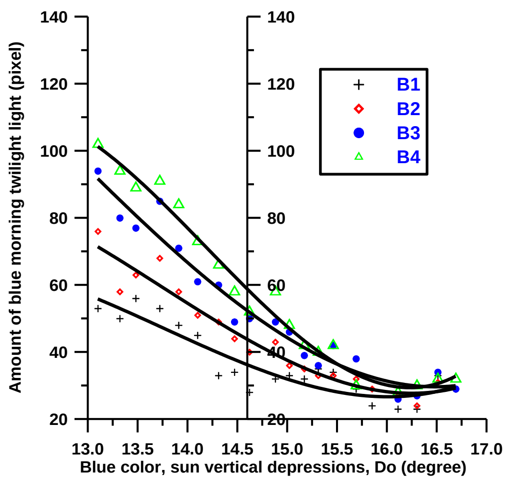
D_o	15.5	15.2	15	14.8	14.6	14.5	14.3	14.2	14	13.7	13.5
WAZ	20	30	50	70	80	80	80	80	80	80	80

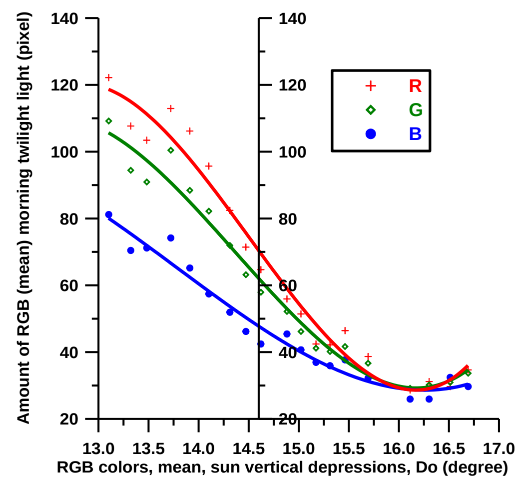
Figure 1 illustrates the progression of morning twilight light observed in Riyadh, KSA, on March 3, 2005, as a gradation of color intensity (in pixels). The relationship between solar depression angle (Do) and light intensity was analyzed for four different heights (hi), where i = 1 to 4, representing approximate heights of 1°, 2°, 3°, and 4°, respectively. Color intensities were measured for the three primary colors (Red, Green, and Blue), their mean (RGB), total intensity (R+G+B), and color indices (B-G, B-R, G-R). Analysis of these curves reveals a critical threshold at Do = 16.2°, below which color discrimination becomes discernible to the human eye. True color discrimination is observed at Do = 14.6°, coinciding with a horizontal light width (WAz) of 80°. At this point, the human eye can clearly distinguish colors. The dominant color observed across these curves is red, followed by green, and then blue (R > G > B).

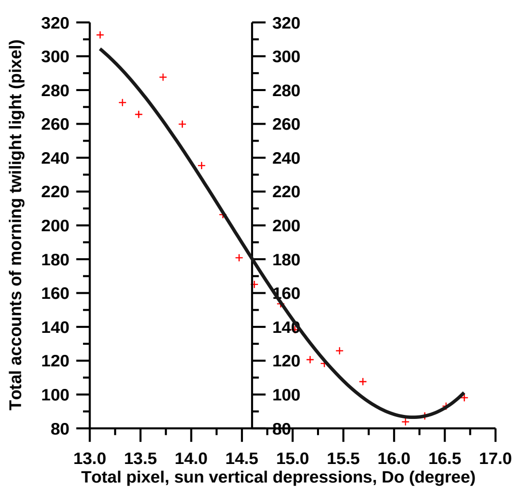
The threshold thickness of the human eye for color perception is estimated to be approximately 100 pixels, determined by the difference in pixel counts between Do = 16.2° and Do = 14.6°. The gradation of color indices during this period follows the order (B-G) > (G-R) > (B-R). Inflection points in the third-degree polynomial fit for these indices occur at the following maxima and minima: (B-G) = 0.35 and -0.05, (G-R) = 0.15 and 0.00, and (B-R) = -0.05 and 0.00, respectively. The (B-G) color index exhibits positive values (maximum of 0.35) at the onset of true dawn (Do = 13.75°) and a minimum value of 0.05 at the end of false dawn (Do = 16.25°), which typically occurs within the range of 17° ≤ Do ≤ 19° [3].


Amount of red morning twilight light (pixel)
Red color, sun vertical depressions, Do (degree)
R1
R2
R3
R4


Amount of green morning twilight light (pixel)
Green color, sun vertical depressions, Do (degree)
G1
G2
G3
G4


Amount of blue morning twilight light (pixel)
Blue color, sun vertical depressions, Do (degree)
B1
B2
B3
B4


Amount of RGB (mean) morning twilight light (pixel)
RGB colors, mean, sun vertical depressions, Do (degree)
R
G
B


Total accounts of morning twilight light (pixel)
Total pixel, sun vertical depressions, Do (degree)

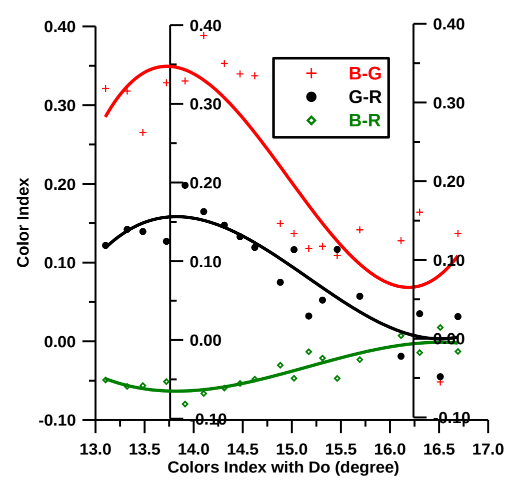

Color Index
Colors Index with Do (degree)
B-G
G-R
B-R

Figure 1 the morning twilight light at Riyadh (KSA, 3rd March 2005) as a gradation of color intensity (in pixels) with Do (degree) for four different heights, hi (i = from 1 to 4 (degree), for the three primary colors, R, G, and B, mean of RGB, total intensity (R+G+B) and color indices of (B-G), (B-R), (G-R).

Figure 2 graphically depicts the relationship between the solar depression angle (Do) and the onset of false dawn and true dawn in Riyadh, KSA. The observed onset of false dawn, at Do = 18.58° ± 0.852, exhibits strong agreement with the findings of Rozenberg (page 18), who reported that the transition to complete night typically occurs within the range of 17° ≤ Do ≤ 19° [15]. The onset of true dawn was observed at Do = 14.58° ± 0.303, resulting in a difference of approximately 4° between the onset of these two phenomena.

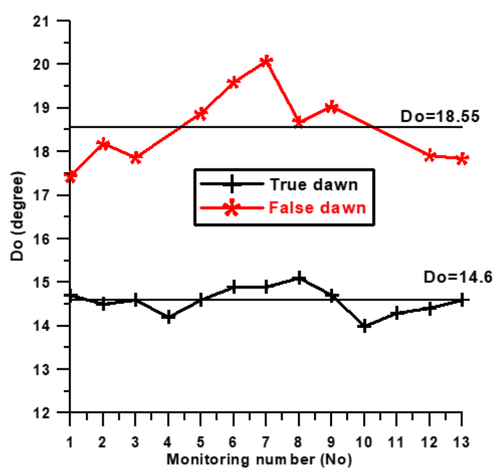


Figure 2 the relationships between the monitoring number (No) of Do (degree) for both the false dawn and true dawn at Riyadh (KSA).

Table 7 presents the results of morning twilight observations (false dawn and true dawn) conducted in Riyadh, KSA, from February 2004 to March 2005. The data encompasses.

observations from specific days within each month, characterized by good visibility. The table includes parameters such as lunar phase (f), moon altitude (Ma), and relative azimuth of the sun and moon. During the last quarter of the moon, with the moon below the horizon (0.111 ≤ f ≤ 0.875), the onset of true dawn was observed at Do = 14.7° ± 0.28 on the 8th morning. When the moon was located above the horizon during the last quarter (0.44 ≤ f ≤ 0.57), the onset of true dawn occurred at Do = 14.6° on the 2nd morning, indicating no discernible difference in morning twilight intensity. For a full moon (f = 0.979) on December 28, 2004, the onset of true dawn was observed at Do = 14.3° under excellent visibility conditions. Color gradient analysis during true dawn revealed the following order of intensity; Red > Green > Blue.

Table 7 the results of Do (degree) for morning twilight observations by the N.E (false dawn and true dawn) and the properties of moonlight; as the phase of the moon (f), positions of the moon (NM, FQ, FM, and LQ), moon altitude (Ma, degree) and the relative azimuth of the sun-moon (Rel. Az, degree).

Date	D_o (false dawn)	D_o (true dawn)	Moon position	Ma, degree	Rel Az, degree	F
27-2-2004	17.43	14.7	FQ	-44.43	-88.2	0.40
2-4-2004	18.18	14.5	FQ	-10.2	216.5	0.86
12-5-2004	17.86	14.6	LQ	31.82	71.46	0.438
28-5-2004	---	14.2	FQ	-36.63	248.3	0.574
24-6-2004	18.87	14.6	FQ	-51.64	285.42	0.332
23-7-2004	19.59	14.9	FQ	-63.93	298.74	0282
27-8-2004	20.08	14.9	FQ	-27.54	181.04	0.875
24-9-2004	18.68	15.1	FQ	-43.74	176.57	0.764
17-10-2004	19.03	14.7	FQ	-54.22	1.65	0.111
26-11-2004	---	14.0	FM	5.51	183.8	0.994
28-12-2004	--	14.3	FM	30.14	177.45	0.979
7-2-2005	17.92	14.4	LQ	1.56	20.72	0.052
3-3-2005	17.84	14.6	LQ	39.14	88.48	0.573
Mean	18.548	14.58				
SD	0.8525	0.303				

4.2 For Mauritania, (Mur.1 and Mur.2)

Table 8 presents the statistical analysis of solar depression (Do) values at the onset of true dawn for both Mur.1 and Mur.2 locations in Mauritania. The analysis reveals a high degree of homogeneity among the mean (14.24°), median (14.32°), and mode (14.48°) values of Do, with minimal differences observed between these measures (approximately 0.24°). The onset of true dawn was determined to occur at Do = 14.85° (14.24° ± 0.61°).

Table 8 represents the different statistical values of Do (degree) for two sites in Mauritania (Mur.1 and Mur.2) as well as the morning observations in the 10th day.

D_o, degree						
Min	Max	Range	Mean	Median	Mode	SD
13.32	14.94	1.62	14.245	14.325	14.485	0.61

Table 9 presents key factors influencing morning twilight observations in Mauritania (Mur.1 and Mur.2) for January 2024. These factors include solar depression (Do), sun azimuth (Saz), moon altitude (Ma), moon azimuth (Maz), lunar phase (f) ranging from 0 to 1, and moon position (New Moon, NM; First Quarter, FQ; Full Moon, FM; Last Quarter, LQ). These data are derived from observations conducted during periods of exceptionally good visibility. Observations summarized in Table 9 indicate that the intensity of morning twilight light remains largely unaffected by the moon's position above or below the horizon, particularly during the last quarter phase. For lunar phases with $0.00 \leq f \leq 0.30$, the onset of true dawn was observed at Do = 14.3° ± 0.6° with a relative azimuth (Δaz) of approximately 90°. The greatest effect of the moon is in the case of a full moon (f ≈1), where Do = 14.42° (Mur.1),

Table 9 the important factors affecting morning twilight forecasts in Mauritania (Mur,1 and 2) for January 2024, KSA (Riyadh, 28th Dec. 2004) as; sun vertical depression Do, Saz, Ma, Maz, f, Moon position (NM, FQ, FM, and LQ).

Date	D_o (-a) degree	Saz (degree)	Ma (degree)	Maz (degree)	Δaz (degree)	*f*,	Moon position
6 Jan, Mur.1	14.88	108.87	43.54	141.6	-32.73	0.3	LQ
7 Jan, Mur.1	14.94	108.39	32.67	134.95	-26.56	0.21	LQ
8 Jan, Mur.1	14.78	108.63	21.41	129.62	-20.99	0.13	LQ
11 Jan, Mur.2	14.65	108.3	-14.88	114.29	-5.99	0.002	NM
12 Jan, Mur.2	14.47	108.18	-27.1	108.04	0.14	0.1	NM
16 Jan, Mur.2	14.16	107.53	-64.35	44.77	62.76	0.29	FQ
17 Jan, Mur.2	14.18	107.32	-63.76	14.74	92.58	0.4	FQ
19 Jan, Mur.2	13.32	107.15	-49.7	336.35	-229.2	0.62	FQ
21 Jan, Mur.2	13.33	106.7	-30	317.19	-210.49	0.81	FQ
26 Jan, Mur.1	14.42	105.0	21.03	285.9	-179.1	0.996	FM

4.3 For 15th May City

Table 10 presents the statistical analysis of solar depression (Do) values at the onset of true dawn on 15th of May City, Egypt. The mean, median, and mode values of Do exhibit a high degree of homogeneity, with minimal differences observed (approximately 0.24°): 11.83°, 11.6°, and 11.07°, respectively. The onset of true dawn was determined to occur at Do = 12.69° (11.88° ± 0.81°). The observed range of Do values in the 15th of May City (ΔDo = 3.38°) suggests a relatively low visibility due to the proximity of the city to Helwan, an industrial area located 10 km to the west. Wind direction analysis (Table 4) reveals that northerly and north-easterly winds account for approximately 50% of the total wind direction, while westerly winds (NW & SW), originating from the Helwan industrial complex (cement and steel factories), contribute approximately 8.49%. These westerly winds are a significant source of atmospheric pollution in the 15th of May City. The observed onset of true dawn at Do = 12.69°, which is approximately 2° lower than the average value observed in desert regions (Do = 14.7°), represents a 14.5% decrease. This discrepancy can be attributed to the influence of local air pollution from the Helwan industrial complex, particularly due to the prevailing westerly winds.

Table 10 represents the different statistical values of Do (degree) for 15th May City and the number of morning observations taken was 41th day.

D_o, degree						
Min	Max	Range	Mean	Median	Mode	SD
11.08	14.46	3.38	11.881	11.61	11.068	0.81

5. The effect of the full moon's light on seeing the true dawn in different places

Table 11 presents an analysis of the effect of full moonlight on the observation of true dawn in three countries situated within 5° N latitude. The data encompasses observations from Riyadh (Table 7), Mauritania (Table 9), and Aswan (Table 3, Figures 12 & 15, Marzouk et al., 2024).

5.1 In Riyadh, KSA (25°46' N), on December 28, 2004, naked-eye observations were conducted to determine the onset of true dawn. Under full moon conditions, the onset of true dawn was observed at Do=14.27°.

5.2 In Aswan, Egypt (23°48.2' N), on December 26th, 2015, observations of morning twilight were conducted using a Nikon D5200F camera and the naked eye. The onset of true dawn was determined to occur at Do = 14.4°. Figures 3a and 3b (from Table 3 and Figures 12 & 15, Marzouk et al., 2024) illustrate the variation of color intensity (red, green, blue) and total intensity as a function of Do. These figures reveal a minimum in color intensity within the interval 15° ≤ Do ≤ 16°, corresponding to the period between the end of false dawn and the onset of true dawn. The observed color intensity order was R > G > B throughout the twilight period. The maximum color intensity of false dawn was observed at Do ≈ 19.5° ± 1°. These observations indicate that the presence of a full moon had no significant impact on the observed values of Do for either false dawn or true dawn. A comparison of true dawn onset in Riyadh (Do = 14.27°) and Aswan (Do = 14.4°) reveals strong agreement, both in terms of Do and the observed color gradient intensity (R > G > B).

5.3 In Mauritania (20°51' N), on January 26, 2024, naked-eye observations revealed the onset of true dawn at a solar depression (Do) of 14.42° during a full moon. The maximum lunar influence on true dawn observations was observed during full moon conditions (f ≈ 1), with Do values of 14.42° (Mauritania), 14.4° (Aswan), and 14.27° (Riyadh). During these observations, the moon's elevation (Ma) above the horizon was 21.03°, 30.12°, and 19.6°, respectively, and the moon's horizontal angle was ≈180° opposite the direction of true dawn. Table 11 presents data from observations conducted in three different countries within the northern equatorial region during winter months (January and December) under excellent visibility conditions. These observations, conducted by different observers using both naked-eye and camera techniques, demonstrate a strong agreement regarding the effect of a full moon on the onset of true dawn, with all observations converging around Do = 14.4°.

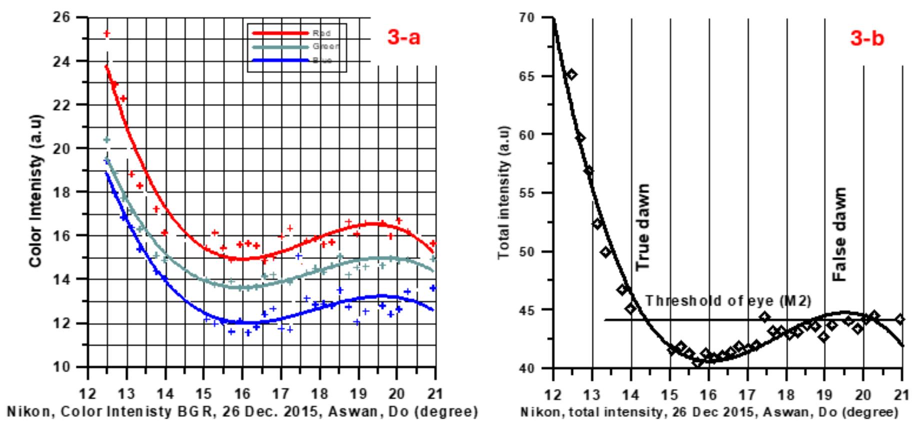


Fig. 3 a&b (figures 12 and 15 [26]), the variation of C.I (a.u) and T.I (a.u) with Do (degree) of BGR colors for the morning twilight on 26th Dec. 2015 in Aswan.

Table 11 the effect of the full moon's light conditions on seeing the true dawn in different three countries, as a filtered observation of Riyadh (table 7), Mauritania (table 9), and Aswan (table 3 and Figure 12&15, [26]).

Date	D_o (degree)	Saz (degree)	Ma (degree)	Maz (degree)	Δaz (degree)	f	Moon position
28th Dec. 2004, Riyadh	14.27	109.26	30.12	286.7	-177.44	0.979	FM
26th Dec. 2015, Aswan	14.4	109.5	19.58	281.38	171.85	0.993	FM
26th Jan, 2024, Mur.1	14.42	105.0	21.03	285.9	-179.1	0.996	FM

6. Conclusions

In any field-based study of twilight phenomena, naked-eye observations should be accorded the highest priority, particularly within the visible spectrum of human vision. The human visual system exhibits an exceptional capacity for color discrimination, capable of distinguishing approximately 7 to 10 million different colors, a level of sensitivity that surpasses any existing instrument [42]. A primary objective of this research was to determine the solar depression angle (Do) at the onset of true dawn and to investigate the factors influencing its visibility.

The present study summarizes the findings of observations conducted in three distinct geographical regions; all situated within 10° N latitude in the Northern Hemisphere.

6.1 For Riyadh, KSA (selected clean days), the transverse light of true dawn spreads and expands over time starting at Do =14.6˚ when the horizontal amplitude of light reaches WAZ=80˚. The color gradient intensity of light during true dawn is R>G>B. The false dawn is at Do =18.58°±0.852, this result is completely consistent with Rosenberg 1966 (page 18) said the transition to complete night is usually when the sun's vertical depression is ranged 17˚≤Do ≤19° [15], while true dawn is at Do =14.58°±0.303, and the difference between the false and true dawn is about Do ≈4˚. The true degree of dawn in the different phases of the moon is: when the moon is below the horizon (FQ), the true dawn is at Do = 14.7°± 0.28 (0.111≤f≤0.875). And in case the moon is above the horizons (LQ), Do =14.6˚ (0.44 ≤f≤0.57). While In the case of the full moon (FM), the true dawn is at Do =14.3° (f=0.979).

6.2 For Mauritania, Mur.1&Mur.2 (10th morning days), the true dawn in the two sites is Do =14.85° (14.24°±0.61) and the observation place is in the deep desert (the visibility is very good). The effect of the moon phases on seeing the true dawn, this effect is weak in the case of the last quarter. The effect is clear in the case of a full moon, where the light of true dawn is distinguished from the light of the moon at the degree of Do = 14.42°.

6.3 For 15th May City in Egypt, has low visibility (41 morning observation days) on the eastern side of the city of Helwan (where the east is completely open and does not contain any pollutants or human activity) gives the true dawn time of Do =12.69° (11.881°±0.811) and it is low visibility, a decrease of Do ≈ 2˚ (14.5%), where the values of Do =14.7 which represents the very good results from the previous work as the results from the deep desert areas in a different country (see table 1). This difference in the decrease between the optimal value and the observed values in this region (Do ≈2˚) is due to the percentage of westerly winds (NW & SW) being 8.49% (which comes from the source of pollutants, the iron and steel factory and the National Cement factory at that time, 2015-2016). Wind directions play an essential role in the visual range for observing the true dawn phenomenon (especially in the desert areas adjacent to industrial cities).

6.4 To compare the result of the appearance of true dawn with the naked eye and camera for three days in different countries (within a narrow latitude ≈5˚ north) with similar climatic conditions, especially in the presence of a full moon (FM, f≈1) and the azimuth deviation difference is Δaz ≈ 180˚. One day in Aswan (Egypt) [26] gave a value of Do =14.4°, and the other in Mauritania is at Do =14.42°, and in Riyadh (KSA) it was Do = 14.27°. Hence, the effect of the full moon's light on the appearance of the true dawn in three different locations indicates great agreement in the results, all of which revolve around Do = 14.4˚. While there is no effect of the moonlight on the degree of true dawn (Do) in the case of the last quarter (LQ, f≈0. 5).

7. Future work

To enhance the robustness of our findings, it is imperative to conduct comprehensive monitoring of true dawn under a variety of lunar phases. This necessitates the implementation of a multi-faceted observational approach, incorporating both naked-eye observations and instrumental measurements.

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