

Application of Jean Meeus Astronomical Algorithms in Formulating a Unified Global Hijri Calendar

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Abstract

Indonesia should have a trusted institution to determine the beginning of the Hijri month. To date, the determination of the beginning of the Hijri month has not been standardized because each Islamic community organization has its own criteria. One of the criteria that will be discussed in this study is the 2016 Istanbul criteria which gave birth to the concept of a Unified Global Hijri Calendar. However, fulfilling these criteria method is still not agreed upon by experts, making it difficult to socialize to the public. This calendar has been used since 1447 AH/2025 AD. This study aims to provide a deeper understanding of these criteria and also attempts to implement Jean Meeus' astronomical algorithms to obtain the necessary ephemeris data. During the research process, regional datasets will be prepared according to their respective topographical conditions. The data used include the name of the region, the name of the country, latitude, longitude, and altitude. From the preparation, information will be obtained in the form of regions that can represent the time of the beginning of the Hijri month.

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A. Introduction

As a country with the largest Muslim population in the world, Indonesia should have a trusted institution in determining the time of the beginning of the Hijri month. Of course, the stipulation is an important need so that the worship time at the beginning of the month is appropriate and uniform for all regions of Indonesia. However, until now there are still different criteria used by Islamic community organizations or the government [1]. Each criterion has its own scientific explanation and has its own advantages and disadvantages. However, all of these criteria must meet the standards of the Hijri calendar as set forth in the Qur'an and Hadith as follows [2].

1. It is a lunar calendar (kamariyah),

2. The number of months in a year is equal to twelve months,
3. No intercalation (addition of months),
4. The number of days in a month is at least 29 days and a maximum of 30 days, and
5. It is based on the synodic cycle which is characterized by *ijtimak* (conjunction) events.

One of the efforts offered in overcoming these differences is by introducing the concept of the Global Hijri Calendar. As the name implies, the calendar is international, not local or regional as the previous criteria were. The Global Hijri Calendar is divided into two types, namely the Single Global Hijri Calendar and the Zonal Global Hijri Calendar. The Single Global Hijri Calendar is a calendar with the principle of one day and one date around the world. This principle assumes that the entire surface of the earth is a date zone (*matlak*). In the Single Global Hijri Calendar, the new moon always starts simultaneously around the world. Meanwhile, the Global Zonal Hijri Calendar divides the earth into several date zones. There are several versions of the calendar. The disadvantage of the calendar is that one date zone can set the beginning of the month whose date is quite different from the other zones. An example of a Single Global Hijri Calendar is the calendar agreed in Istanbul in 2016. Meanwhile, an example of the Global Zonal Hijri Calendar is the Universal Hijri Calendar [2].

In this study, the researcher is interested in discussing how to implement the Single Global Hijri Calendar (KHGT), especially the 2016 Istanbul calendar. The calendar has been used since 1447 H/2025 AD [3]. The problem is how to meet the criteria given on the calendar? Until now, the concept and significance of the calendar are still not understood. Even astronomers, astronomers, and also sharia and fiqh have not understood much of the principles contained in KHGT in general [4]. There have been attempts to implement the Istanbul calendar as can be seen in [5]. However, the dataset contained in the study is still too few and does not describe the actual topography of the area. Therefore, researchers will increase the amount of regional data and adjust to their respective topographic conditions.

B. Method

The approach taken to solve the previous problem is as follows.

1. Problem Identification

The problem identified in this study is the preparation of algorithms for the fulfillment of the KHGT criteria. The criteria in question are as follows [6].

- ...
2. A new moon begins when in any part of the world, before 24:00 UT, the following criteria have been met: an elongation of 8

degrees or more, and the height of the moon above the horizon at sunset of at least 5 degrees or more (elongation and height of the geocentric moon).

- ...
4. If the above criteria are met after midnight at 24.00 UT, then the new month will still start with the following conditions:
 - a. If the above parameters have been met anywhere in the world and *ijtimak* in New Zealand occurs before dawn.
 - b. The above parameters in point 1 occur in the mainland region of the American Continent.

2. Purpose Formulation

In this study, the researcher will try to use astronomical algorithms as a basis for consideration of the fulfillment of the KHGT criteria.

3. Methodology Selection

The selected algorithm is adjusted to the needs of the system. Based on the criteria described earlier, there are six basic Jean Meeus algorithms used as follows.

- a. Convert AD dates to JDN (*Julian Day Number*) and vice versa [7].
- b. Instant conversion of AD time to JD (*Julian Date*) and vice versa [7].
- c. New moon time *for a certain time of the new moon* [7].
- d. The value of ΔT for a given AD date uses polynomials [8].
- e. Solar ephemeris *data* that include longitude, rectangular ascension, declination, geocentric distance, semi-diameter, obliquity, and time [7].
- f. Lunar ephemeris *data* that include longitude, latitude, rectal ascension, declination, horizontal parallax, and distance [7].

The six basic algorithms were then lowered into five algorithms to meet the KHGT criteria as presented in Table 1 below.

Table 1. Derivative Algorithm for Fulfilling KHGT Criteria

Derived Algorithms	Parameters	Basic Algorithm					
		a	b	c	d	e	f
Conjunction time (<i>ijtimak</i>)	Hijri year and month	✓	✓	✓	✓		
Sunset time (<i>ghurub</i>)	AD date and location data				✓	✓	
Geocentric hilal elongation (arc distance)	Instant time AD					✓	✓
Geocentric hilal height	Instant time and location data				✓	✓	✓

Sunrise time	AD date and location data				✓	✓	
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The five derivative algorithms can be briefly explained as follows.

- The conjunction time (*ijtimak*) is searched using a new moon time search algorithm modified for the Hijri calendar system [9].
- The sunset time (*ghurub*) was searched using the Maghrib prayer time search algorithm [10], but without *ihityat* [9].
- The elongation (arc distance) of the geocentric hilal, JB_{geo} , is sought using the following formula [11]. If on a certain date (AD) and clock, the declination of the sun is obtained as δ_m , the declination of the previous month, the rectangular axis of the sun is δ_b , and the rectangular axis of the moon is α_m , then

$$JB_{geo} = \text{acos}(\sin \delta_m \times \sin \delta_b + \cos \delta_m \times \cos \delta_b \times \cos(\alpha_m - \alpha_b))$$
- Geocentric moon heights are searched using the help of local time to dynamic time conversion algorithms and vice versa [9].
- The time of dawn is searched using the algorithm for finding the time of the Fajr prayer [10], but without *ihityat*.

4. Data Collection

The data collected came from *the* dataset of regions in the world according to their topographic conditions taken from Geonames [12]. The data includes the name of the region, the name of the country, latitude, longitude, and elevation (elevation).

5. Data Preprocessing

The dataset that has been obtained will be handled by completing the lost data fields with a different approach or deleting them if they are completely unrecoverable. The data handling resulted in 146,830 rows (*records*) that were ready to be processed. A snapshot of *the dataset* used can be seen in Table 2 below.

Table 2. Snapshot of the Regional Dataset

Region Name	Country	Latitude	Longitude	Height
...
'Ayn Shiqaq	Syria	35,39441	36,03012	236
São Paulo	Tunisia	35,39444	11,04361	8
Hongnong	South Korea	35,39587	126,44531	36
Fruitland	United States	35,39651	-82,39317	675
Mascara	Algeria	35,39664	0,14027	590
Chonan	Japan	35,39701	140,23503	41
Mount Pleasant	United States	35,39931	-80,4359	191

Isehara	Japan	35,39932	139,31019	35
Lillington	United States	35,39933	-78,81585	59
...

6. Testing and Implementation of Algorithms

At this stage, the selected algorithm will be tested with the appropriate programming language, such as Kotlin. To facilitate implementation, the previous criteria will be *broken down* as seen in Figure 1.



Figure 1. Breakdown of the Criteria for the Beginning of the Hijri Month at KHGT

The beginning of the next Hijri month starts the next day if one of the Global Calendar Parameters (PKG) 1 or 2 is met. If not, it will be done *istikmal* so that the running month is 30 days old and the next month will only start the day after tomorrow. How to use *the breakdown of these criteria is as follows.*

- a. First of all, do *an ijtimak* time search using a conjunction time search algorithm.
- b. For condition 1A, just compare the time of *ghurub* and *ijtimak*.
- c. For requirements 1B to 1D, iterate on each data in the *dataset* until the first area that meets these criteria is found. If the iteration is stopped because the reading of the location *dataset* has reached the last row that does not meet, it is certain that PKG 1 is not met.
- d. For requirement 2A, search for sunrise time by filtering *the dataset* so that only the data in New Zealand are available. The dawn time sought is the earliest local dawn time (in UTC) of the entire region.
- e. For conditions 2B through 2D, do the same iteration process as point c, but for the next day.

- f. For the 2E requirement, first provide a new *dataset* which is a screening of the initial *dataset* that leaves only regional data in the North and South American continents. This means that areas far from the parent country (such as Hawaii) are not filtered. Then, compare the results of the calculation at point e. If the first area is in the new *dataset*, it can be said that PKG 2 may be met, depending on the results of the calculation in point d.

C. Results and Discussion Research Results

Implementation process *Breakdown* The KHGT criteria to the selected programming language results in a terminal-based program (console) as can be seen in Figure 2.

```

Project: KHGT - Version control
Run: Tester_global.kt
C:\Program Files\Java\jdk-9.0.4\bin\java.exe *javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2023.3.3\lib\idea_rt.jar=55330:c:\p...
Memuat data lokasi keseluruhan... 140.830 data lokasi berhasil dimuat

Tahun Hijriyah: 1447

          DAFTAR BULAN HIJRIYAH
[1] Muharran   [2] Safar     [3] Rabiul Awal  [4] Rabiul Akhir
[5] Jumadil Awal [6] Jumadil Akhir [7] Rajab         [8] Syaban
[9] Ramadhan   [10] Syawal    [11] Dzulqaidah  [12] Dzulhijjah
Bulan Hijriyah (1-12): 9

=====
[RAMADHAN 1447]
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Waktu ijtima: 17 Februari 2026 12:02:21.17972105741500854 UTC

*****PARAMETER KALENDER GLOBAL 1*****
Mencari daerah yang memenuhi kriteria sebelum pukul 24 UTC...
DAERAH YANG MEMENUHI KRITERIA TIDAK DITEMUKAN
Data daerah terakhir:
Nama daerah: Longyearbyen, Norway
Lintang: 78° 13' 24.0239999997350° LU
Bujur: 15° 38' 48.80400000000307° BT
Ketinggian: 1.0 mdpl

Jan ghurub: 12:37:42.7175017350385820 UTC
Elongasi hilal geosentrik: 0° 56' 42.10028350240563"
Tinggi hilal geosentrik: -1° 33' 39.582703314643002"

*****PARAMETER KALENDER GLOBAL 2*****
Mencari waktu terbit fajar di Selandia Baru...
Jan terbit fajar di Selandia Baru: 10:02:18.4087373190672588 UTC
Nama daerah: Castlepoint
Lintang: 40° 53' 59.99999999994884° LS
Bujur: 176° 13' 0.011999999976524123° BT
Ketinggian: 27.0 mdpl
WAKTU TERBIT FAJAR DI SELANDIA BARU MEMENUHI KRITERIA

Mencari daerah yang memenuhi kriteria setelah pukul 24 UTC...
DITEMUKAN DAERAH YANG MEMENUHI KRITERIA:
Nama daerah: Rada Tilly, Argentina
Lintang: 45° 55' 28.6319999999904° LS
Bujur: 67° 33' 15.263999999974658° BB
Ketinggian: 10.0 mdpl
Jan ghurub: 47:38:54.47088885607532 UTC
Elongasi hilal geosentrik: 18° 19' 57.747869612982100"
Tinggi hilal geosentrik: 5° 1' 15.0614117205757"
DAERAH YANG MEMENUHI KRITERIA BERADA DI BENUA AMERIKA

Kesimpulan: 1 Ramadhan 1447 = 18 Februari 2026

Ulangi untuk bulan dan/atau tahun Hijriyah yang lain?
    
```

Figure 2. Criteria Breakdown Implementation Program

First of all, the program asks for *input* in the form of the year and month of Hijri. Then, the program performs a computational process on each data in the *dataset*. The program will calculate *the ijtima* time first. The compute results are still displayed even if no conditions are met. If PKG 1 is not met, then the program will display the results of the last data processing.

Next, the program will calculate the time of sunrise in New Zealand. The iteration process for the initial *dataset* is repeated again for the next day in the hope that the first data that meets the criteria will be in the *filtered dataset*. Finally, the program will display a conclusion regarding the beginning of the Hijri month that has been included previously. The recapitulation of the results of the calculation at the beginning of the month for the year 1447 H can be seen in Table 3 for the time of *ijtimak* and the fulfillment of PKG 1 and Table 4 for the fulfillment of PKG 2. In both tables, (+1) indicates that the value or parameter in question occurred or was calculated for the next day.

Table 3. Recapitulation of the Results of the Calculation of the Beginning of the Month 1447 H (*Ijtimak* Time and PKG 1)

Moon	<i>Ijtimak</i>	<i>Ghurub</i>	Elongation	Height
Muharram	June 25, 2025 10:32:40,03	22:56:39,04	8° 24' 45,72"	5° 0' 0,46"
Safar	July 24, 2025 19:12:20,32	05:05:11,1 (+1)	6° 15' 6,12"	1° 30' 40,81"
Rabiul Awal	August 23, 2025 06:07:39,6	22:12:35,61	8° 2' 50,63"	5° 31' 58,08"
Rabiul Akhir	September 21, 2025 19:55:08,27	17:16:27,95	1° 31' 14,24"	-1° 27' 27,41"
Jumadil Awal	October 21, 2025 12:26:16,29	12:51:24,3	3° 22' 9,61"	-4° 10' 38,86"
Jumadil Akhir	November 20, 2025 06:48:32,11	22:21:44,78	8° 35' 9,25"	7° 28' 53,06"
Rajab	December 20, 2025 01:44:38,93	23:02:10,11	10° 46' 49,07"	7° 32' 31,64"
Shaban	18 January 2026 19:53:13,62	10:38:30,3	5° 44' 20,46"	-5° 38' 18,11"
Ramadan	17 February 2026 12:02:21,18	12:37:42,72	0° 56' 42,1"	-1° 33' 39,58"
Shawwal	March 19, 2026 01:24:41,38	22:55:17,36	12° 3' 16,33"	5° 3' 44,07"
Dzulqaidah	April 17, 2026	23:54:18,98	8° 7' 6,9"	5° 2'

	11:52:59,94			46,81"
Dzulhijjah	May 16, 2026 20:02:09,57	22:26:29,77	5° 9' 15,58"	4° 12' 56,79"

Table 4. Recapitulation of the Results of the Initial Calculation of the Month 1447 H (PKG 2)

Moon	Dawn NZ	Ghurub (+1)	Elongation (+1)	Height (+1)	In America?
Muharram	17:48:27,6	20:19:12,48	19° 15' 52,2"	5° 14' 22,83"	Yes
Safar	17:41:23,34	20:45:13,65	13° 45' 9,62"	6° 21' 41,96"	Yes
Rabiul Awal	17:12:15,12	17:01:31,57	17° 12' 45,18"	8° 1' 18,72"	No
Rabiul Akhir	16:28:24,84	19:56:09,6	11° 28' 21,54"	7° 33' 26"	No
Jumadil Awal	15:36:08,71	23:25:30,66	16° 28' 45,98"	10° 19' 30,3"	No
Jumadil Akhir	14:30:30,13	17:51:40,22	16° 37' 36,88"	8° 18' 31,38"	No
Rajab	13:54:29,32	10:02:33,16	15° 30' 44,94"	9° 30' 41,16"	No
Shaban	14:49:49,6	22:48:53,03	13° 11' 52,72"	5° 8' 57,39"	Yes
Ramadan	16:02:18,47	23:38:54,47	18° 19' 57,74"	5° 1' 15,66"	Yes
Shawwal	16:41:06,15	22:38:19,99	25° 9' 15,7"	5° 7' 15,75"	Yes
Dzulqaidah	17:08:06,68	22:25:21,89	20° 30' 44,12"	5° 2' 6,6"	Yes
Dzulhijjah	17:30:04,86	21:04:30,08	15° 40' 35,87"	5° 0' 40,73"	Yes

Discussion

From the results of the calculation of the beginning of the month for the year 1447 H as presented in Tables 3 and 4, analysis and conclusions can be drawn for each month as follows.

a. Muharram

PKG 1 is **fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Muharram 1447 H falls on **June 26, 2025** (one day after the date of *ijtimak*).

b. Safar

PKG 1 **was not fulfilled** because until the last regional data, no area was found with a geocentric hilal elongation of at least 8° and a geocentric hilal height of at least 5° at the *time of ghurub*. Meanwhile, PKG 2 was also **not fulfilled** because the dawn in New Zealand rose before *ijtimak* even though *the ghurub*, elongation, and height of the geocentric hilal have been fulfilled at least in the Americas, so that the beginning of the month of Safar 1447 H falls on **July 26, 2025** (two days after the date of *ijtimak*).

c. Rabiul Awal

PKG 1 is **fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Rabiul Awal 1447 H falls on **August 24, 2025** (one day after the date of *ijtimak*).

d. Rabiul Akhir

PKG 1 **was not fulfilled** because until the last regional data, no area was found with a geocentric hilal elongation of at least 8° and a geocentric hilal height of at least 5° at the *time of ghurub*. Meanwhile, PKG 2 is also **not fulfilled** because the dawn in New Zealand rises before *ijtimak* and also *ghurub*, elongation, and geocentric hilal height are at least not fulfilled in the Americas, so the beginning of the month of Rabiul Akhir 1447 H falls on **September 23, 2025** (two days after the date of *ijtimak*).

e. Jumadil Awal

PKG 1 is **not fulfilled** because even though *ghurub* occurs after *ijtimak*, the elongation of the geocentric hilal does not reach 8° and the height of the geocentric hilal does not reach 5° during *ghurub*. Meanwhile, PKG 2 is also **not fulfilled** because even though the dawn in New Zealand rises after *ijtimak*, *ghurub*, elongation, and geocentric hilal height are at least not fulfilled in the Americas, so the beginning of the month of Jumadil Awal 1447 H falls on **October 23, 2025** (two days after the date of *ijtimak*).

f. Jumadil Akhir

PKG 1 **is fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Jumadil Akhir 1447 H falls on **November 21, 2025** (one day after the date of *ijtimak*).

g. Rajab

PKG 1 **is fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Rajab 1447 H falls on **December 21, 2025** (one day after the date of *ijtimak*).

h. Shaban

PKG 1 **was not fulfilled** because until the last regional data, no area was found with a geocentric hilal elongation of at least 8° and a geocentric hilal height of at least 5° at the *time of ghurub*. Meanwhile, PKG 2 is also **not fulfilled** because although *the ghurub*, elongation, and height of the geocentric hilal have been fulfilled at least in the Americas, the dawn in New Zealand rises before *ijtimak*, so that the beginning of the month of Shaban 1447 H falls on **January 20, 2026** (two days after the date of *ijtimak*).

i. Ramadan

PKG 1 **was not fulfilled** because until the last regional data, no area was found with a geocentric hilal elongation of at least 8° and a geocentric hilal height of at least 5° at the *time of ghurub*. However, PKG 2 **was fulfilled** because the dawn in New Zealand rose after *ijtimak* and at the *time of ghurub* on the following day, the elongation and height of the geocentric hilal at least had been fulfilled in the Americas, so that the beginning of the month of Ramadan 1447 H fell on **February 18, 2026** (one day after the date of *ijtimak*).

j. Shawwal

PKG 1 **is fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Shawwal 1447 H falls on **March 20, 2026** (one day after the date of *ijtimak*).

k. Dzulqaidah

PKG 1 **is fulfilled** because *the ghurub* occurs after *ijtimak* and on the same day, the elongation of the geocentric hilal exceeds or equals 8° , and the height of the geocentric hilal exceeds or equals 5° at *the time of ghurub*. Because PKG 1 has been fulfilled, the fulfillment of PKG 2 can be ignored, so that the beginning of the month of Dzulqaidah 1447 H falls on **April 18, 2026** (one day after the date of *ijtimak*).

l. Dzulhijjah

PKG 1 **is not fulfilled** because even though *ghurub* occurs after *ijtimak*, the elongation of the geocentric hilal does not reach 8° and the height of the geocentric hilal does not reach 5° during *ghurub*. Meanwhile, PKG 2 is also **not fulfilled** because although *the ghurub*, elongation, and height of the geocentric hilal have been met at least in the Americas, the dawn in New Zealand rises before *ijtimak*, so that the beginning of the month of Dzulhijjah 1447 H falls on **May 18, 2026** (two days after the date of *ijtimak*).

D. Conclusion

Based on the results of the research that has been carried out, it can be concluded that the fulfillment of the KHGT criteria is carried out by breaking down the parameters of these criteria into a number of fulfillment requirements. *The breakdown* can then be implemented into the program to facilitate the process of reading and processing regional *datasets*. The parameters that must be met are enough for one of them because the other parameter acts as a correction if the first criterion is not met.

This research is still far from perfect. For further research, it is hoped that it can be further developed, for example by comparing the KHGT criteria with other criteria or by increasing the number of corrections to the *ephemeric* data of the sun and moon.

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