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Prayer Time Calculation Using Approximated Epimeris Data

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Abstract

Prayer time can be determined by observing the movement of the sun or by mathematical calculation. Determining the prayer time by mathematical calculation requires input in the form of ephemeris data. Ephemeris data can be obtained from a table, for example using the winhisab application. Alternatively, ephemeris data can be obtained by mathematical calculation using the approximation method. The data calculated using the approximation method is not exactly the same as the data obtained from winhisab, but the difference is not too great. The prayer schedule calculated with the approximation data should not be too different from the one calculated with the winhisab data

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A. Introduction

Muslims are obliged to pray five times a day. This prayer has a specific procedure and time of performance as described in the Qur'an and the Hadith of the Prophet Muhammad SAW. The command to pray is explained in al-Qur'an Surah an-Nisa verse 103 as follows

فَإِذَاقَضَيْتُمُٱلصَّلَوٰةَفَٱذْكُرُوا ٱللَّهَقِيَٰمًاوَقُعُودًاوَعَلَىٰجُنُوبِكُمْ ۚ فَإِذَاٱطْمَأْنَنتُمْفَأَقِيمُوا ٱلصَّلَوٰةَ ۚ إِنَّٱلصَّلَوٰةَكَانَتْعَلَىٱلْمُؤْمِنِينَكِتَٰبًامَّوْقُوتًا

Translation:*"When the prayers are over, remember Allah—whether you are standing, sitting, or lying down. But when you are secure, establish regular prayers. Indeed, performing prayers is a duty on the believers at the appointed times."*

The Prophet Muhammad SAW also said that one of the most important acts of worship before Allah SWT is to pray at the beginning of time, as narrated in the following Abu-Daud hadith:

عَنْأُمِّفَرْوَةَقَالَتْسُئِلَرَسُولُاللَّهِ -صلىاللهعليهوسلم- أَىُّالأَعْمَالِأَفْضَلُقَالَ « الصَّلاَةُفِىأَوَّلِوَقْتِهَا\

Meaning:*"Umm Farwah narrated: The Messenger of Allah (peace and blessings of Allah be upon him) was asked which deed is the most rewarding. He replied: 'Praying at the beginning of its time.'"* (HR. Abu Daud no. 426.)

Conversely, Allah SWT also threatens Muslims who are negligent in their prayers in al-Quran Surah al-Ma'un, verses 4-5, as follows

فَوَيْلٌ لِّلْمُصَلِّيْنَۙ - الَّذِيْنَ هُمْ عَنْ صَلَاتِهِمْ سَاهُوْنَۙ

Translation: *"So woe to those ˹hypocrites˺ who pray, yet are unmindful of their prayers"*
The specific time of prayer is explained in the following hadith[1]:

عَنْعَبْدِاَللَّهِبْنِعَمْرٍورَضِيَاَللَّهُعَنْهُمَا; أَنَّنَبِيَّاَللَّهِ – صلىاللهعليهوسلم – قَالَ: – وَقْتُاَلظُّهْرِإِذَازَالَتْاَلشَّمْسُ,
وَكَانَظِلُّاَلرَّجُلِكَطُولِهِمَالَمْيَحْضُرْاَلْعَصْرُ, وَوَقْتُاَلْعَصْرِمَالَمْتَصْفَرَّاَلشَّمْسُ, وَوَقْتُصَلَاةِاَلْمَغْرِبِمَالَمْيَغِبْاَلشَّفَقُ,
وَوَقْتُصَلَاةِاَلْعِشَاءِإِلَىنِصْفِاَللَّيْلِاَلْأَوْسَطِ, وَوَقْتُصَلَاةِاَلصُّبْحِمِنْطُلُوعِاَلْفَجْرِمَالَمْتَطْلُعْاَلشَّمْسُ – رَوَاهُمُسْلِمٌ

Meaning:*"'Abdullah ibn 'Amr (may Allah be pleased with him) reported that the Prophet*

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(peace and blessings of Allah be upon him) said: "The time for Zhuhr begins from the time the sun sets until the shadow of the sun reaches the height of the sun, as long as the time for 'Asr has not yet begun. The time for 'Asr prayer is as long as the sun has not turned yellow. The time for Maghrib prayer is as long as the Shafaq (red light) has not disappeared. The time for Isha' prayer is until midnight, and the time for Fajr prayer is from dawn to sunrise." (HR. Muslim, no. 612, 173)

Prayer times can be determined by observing the daily movement of the sun. The time for Zuhr prayer is when the sun has moved to the west, the time for Asr prayer is when the shadow of an object is the same length, the time for Maghrib prayer is when the sun sets, the time for Isha prayer is when the red shroud disappears and the time for Fajr prayer is when the dawn breaks[2]. However, observations can only be made in clear weather conditions. Observations are difficult when the weather is cloudy or rainy. To solve this problem, mathematical formulas have been developed to calculate prayer times. Determining prayer times through mathematical calculations is known as the "astronomical formula".

The calculation of prayer times requires solar data, including: the equation of time (e), the sun's declination (δ)[3], and, for the calculation of the Maghrib prayer time, the sun's semi-declination (SDM). These data can be obtained from the Epimeris table. An application often used by astrologers is *Winhisab*, developed by the Ministry of Religious Affairs of the Republic of Indonesia[4].

In addition to using the epimeris table, data on the equation of time (e), solar declination (δ), and solar semi-diameter (SDM) can also be calculated using the approximation method. The data from this approximation are not exactly the same as the data found in the winhisab application. However, the value of the data differences is generally very small, only in the order of a few seconds[5].This study attempted to determine the degree of accuracy of the prayer schedule calculated using the approximation result data compared to the prayer schedule calculated using the *Winhisab* application data.

B. Methods

This research is quantitative with a comparative approach. The comparison was made between the prayer schedule calculated using the data from the approximation results and the prayer schedule calculated using the data from the Winhisab application.This study has primary data in the form of equation of time (e), sun declination (δ), and sun-half diameter

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(SDM) data calculated using the approximation method, while secondary data are similar data taken from the Winhisab application.

In general, this research is divided into four stages, namely: (1) retrieval of secondary data using the winhisab application, (2) calculation of primary data using the approximation method, (3) calculation of prayer schedules using primary and secondary data, and (4) summary and comparison of prayer schedules calculated using primary and secondary data.

In order to minimise the presence of external variables that may affect the calculation results, it is necessary to have limitations in the conduct of this research. The limitations include:

- The prayer schedule is compiled for one year, from 1 January 2024 to 31 December 2024.
- The data includes only Fard prayer times (Fajr, Zuhr, Asr, Maghrib, Isha), excluding Shuruk and Dhuha prayer times.
- Prayer times are given in hours and minutes only, without seconds.
- The smallest difference in the prayer times is one minute.
- The prayer schedules have been prepared for ten cities, all located in eastern Indonesia. The coordinates of the cities are taken from the book of falak science compiled by Abu Sabda. The following is a list of the ten cities:

Table 1. Coordinates of the city for which the prayer time is calculated

City	Latitude Coordinates	Longitude Coordinates
Ambon	3° 41' S	128° 13' E
Tual	5° 34' S	132° 20' E
Ternate	0° 47' N	127° 21' E
Tidore	0° 26' N	127° 41' E
Sofifi	0° 44' N	127° 34' E
Merauke	7° 55' S	139° 31' E
Jayapura	2° 39' S	140° 27' E
Raja Ampat	0° 24' S	130° 47' E
Manokwari	0° 57' S	133° 49' E
Sorong	1° 12' S	131° 27' E

- The height of the city is assumed to be 0 metres above sea level.
- The calculation of prayer times is done using data from the approximation results and data from the winhisab application.

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- The reference data is the prayer schedule calculated using data from winhisab, assuming that the data is correct.
- The prayer schedule calculated using the approximation results is compared with the prayer schedule calculated using data from winhisab.
- The accuracy value is calculated on the basis of the number of data with the same value from the two compiled prayer schedules.
- All the calculations of prayer times were done by the researchers using the Microsoft Excel application and not using the winhisab application.
- The winhisab application is only used to obtain data on the equation of time (e), solar declination (δ) and solar half-diameter (HR).
- Prayer times are calculated using the same formula and parameters. The only difference is the Epimeris data used, where one is calculated by approximation and the other is taken from the Winhisab application.
- The parameters used in the calculation are the same, as following Fajr sun elevation = -20^o[6], Isha sun elevation = -18^o[7]and Ihtiyat time = 2 menit[8]
- The winhisab application used is version 2.0.

1. Formula for calculating prayer time

The development of science in the field of astronomy is very helpful for Muslims in calculating prayer times. Prayer times no longer have to be determined by direct observation. This is especially helpful when weather conditions are unfavourable.

In general, the formula for calculating prayer times consists of the following components:

- ***Meredian Pass (MP)*** is the moment when the sun reaches its apex. The daily movement of the sun is not always exactly 24 hours, there are times when it is slightly faster or slightly slower. However, the movement of a clock in a day is always a constant 24 hours. The difference between the real time of the sun and the time of the watch is called the equation of time (e). To calculate the value of the Sun's meridian passage, the following formula is used:

  MP = 12:00 – e

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Where e is the equation of time[9].

- **The solar time angle (t)** is the arc along the sun's daily orbit, calculated from the upper culmination point to the sun's current position. The solar time angle is positive (+) when the Sun has passed its apex and negative (-) when the Sun has not passed its apex[10]. The magnitude of the solar time angle can be calculated using the following formula:

$$\cos t = \sin h / \cos \varphi / \cos \delta - \tan \varphi \tan \delta$$

Description:

φ = latitude of place

δ = declination of the Sun

h = altitude of the Sun

- **The Local Time Correction (LTC)** is a correction to the prayer schedule calculated using the GMT formula to local time[11]. The amount of time correction in a region can be calculated using the following formula:

$$KWD = \lambda - (time\ zone \times 15^o)$$

Description:

λ = City Longitude

The territory of Indonesia is divided into three time regions, including: (1) West Indonesia Time with time zone GMT +7, (2) Central Indonesia Time with time zone GMT +8, and (3) East Indonesia Time with time zone GMT +9[12].

- **Ihtiyat (i)**is the safety time added at the end of the prayer time calculation. The addition of ihtiyat time is necessary for the following reasons: (1) the rounding of numbers during the calculation, (2) the schedule of prayer times used for a long period of time (e.g. the schedule of prayer times throughout the period) needs to be corrected because the movement of the sun is not really constant every year, (3) there is a time difference between the area located in the east and the area located in the west, (4) anticipating the difference in altitude in a region[13]. The Ministry of Religious Affairs of the Republic of Indonesia has been using the Ihtiyat time of 2 minutes since 1979 because it is considered sufficient to provide security up to a distance of 55 km to the west and east[14].

From the above explanation, we can formulate the formula for calculating the prayer time as follows:

$$Prayer\ Time = MP + t - KWD + i$$

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Note that for the Zuhr prayer time, the value of t is zero (0) because it is close to the culmination of the sun, and for the Fajr prayer time, the value of t is negative (-) because the sun has not yet passed the culmination point.

2. Calculation of epimeris data using the approximation method

Epimeris data are data published as guidelines or references for the performance of Hisab and Rukyat[15]. To calculate the time of prayer, the following epimeris data are required:

- Declination / *apparent declination* (δ)is the difference between the centre of the sun and the equator. When observed over the course of a year, the position of the Sun always moves from north to south and vice versa. This phenomenon is called the annual apparent motion of the Sun[16]. When the Sun is in the northern hemisphere, the value of the declination is positive (+) and when the Sun is in the southern hemisphere, the value of the declination is negative (-)[9].

- Equation of time (e) is the difference between the real time of the Sun and the time on a clock.

- The Sun's Semi-diameter (SDM) is the distance between the centre of the Sun and its outer layer[17].

In addition to using the epimeris table (Winhisab), the above data can also be calculated using the approximation method[5].

C. Resultsand Discussion

Results

The steps to calculate Epimeris data using the approximation method are explained below. Epimeris data are calculated for 1 June 2023 at 6:00 GMT.

The first step is to set the date, month, year, hours, minutes and seconds as follows:

Steps : 1

Month : 6

Years : 2023

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Hours : 6

Minute : 0

Second : 0

Then calculate the values of Y, M, A and B using the following conditions:

If month is > 2 then

Y = Years

M = Month

If month is $\leq$ 2 then

Y = Year -1

M = Month + 12[18]

If (year + month/100 + step/10000) is $\geq$ 1582,1015, then

A = INT (year/100)

B = 2 – A + INT (A/4)

If (year + month/100 + steps/10000) is < 1582,1015 then

A = 0

B = 0

The above provisions result in:

Y = 2023

M = 6

A = 20

B = -13

Finally, calculate the Julian Day (JD) value using the following formula:

$$JD = INT(365{,}25 \times (Y + 4716)) + INT(30{,}6001 \times (M + 1) + date + B - 1524{,}5 + (hour + minute/60 + second/3600)/24$$

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$JD = INT(365{,}25 \times (2023 + 4716)) + INT(30{,}6001 \times (6 + 1) + 1 + (-13) - 1524{,}5 + (6 + 0/60 + 0/3600)/24$

$JD = 2460096{,}75$

Once the Julian Day (JD) value has been obtained, calculate the following:

Julian Day Centuries (T)

$T = JD - 2451545/36525$ [19]

$T = 2460096{,}75 - 2451545/36525$

$T = 0{,}234134155$

Mean Sun Longitude (S)

$S = 280{,}46645 + (36000{,}76983 \times T)\ mod\ 360$

$S = 280{,}46645 + (36000{,}76983 \times 0{,}234134155)\ mod\ 360$

$S = 8709{,}476262\ mod\ 360$

$S = 69{,}47626228$

Sun Mean Anomaly (M)

$M = 357{,}5291 + (35999{,}0503 \times T)\ mod\ 360$

$M = 357{,}5291 + (35999{,}0503 \times 0{,}234134155)\ mod\ 360$

$M = 8786{,}136312\ mod\ 360$

$M = 146{,}1363116$

Nutation (N)

$N = 125{,}04 - (1934{,}139 \times T)\ mod\ 360$

$N = 125{,}04 - (1934{,}139 \times 0{,}234134155)\ mod\ 360$

$N = -327{,}8072974\ mod\ 360$

$N = 32{,}19270259$

Then calculate the following correction variables:

Correction 1 (C1)

$C1 = (17{,}264/3600) \times \sin N + (0{,}206/3600) \times \sin(2N)$

$C1 = (17{,}264/3600) \times \sin(32{,}19270259) + (0{,}206/3600) \times \sin(64{,}38540517)$

$C1 = 0{,}002606519$

Correction 2 (C2)

$C2 = (-1{,}264/3600) \times \sin(2S)$

$C2 = (-1{,}264/3600) \times \sin(138.9525246)$

$C2 = -0{,}000230569$

Correction 3 (C3)

$C3 = (9{,}23/3600) \times \cos N - (0{,}09/3600) \times \cos(2N)$

$C3 = (9{,}23/3600) \times \cos(32{,}19270259) - (0{,}09/3600) \times \cos(64{,}38540517)$

$C3 = 0{,}002158911$

Correction 4 (C4)

$C4 = (0{,}548/3600) \times \cos(2S)$

$C4 = (0{,}548/3600) \times \cos(138.9525246)$

$C4 = -0{,}0001148008$

Then perform the following variable calculations:

True Obliquity (Q')

$Q' = 23{,}43929111 + C3 + C4 - ((46{,}815/3600) \times T)$

$Q' = 23{,}43929111 + 0{,}002158911 + (-0{,}0001148008) - ((46{,}815/3600) \times 0{,}234134155)$

$Q' = 23{,}4382905$

Mean Sun (E)

$E = (6898{,}06/3600) \times \sin M + (72{,}095/3600) \times \sin(2M) + (0{,}966/3600) \times \sin(3M)$

$E = (6898{,}06/3600) \times \sin(146{,}1363116) + (72{,}095/3600) \times \sin(292{,}2726232) + (0{,}966/3600) \times \sin(438{,}4089347)$

$E = 1{,}049433372$

Sun Longitude (S')

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$S' = S + C1 + C2 + E - (20{,}47/3600)$

$S' = 69{,}47626228 + 0{,}002606519 + (-0{,}000230569) + 1{,}049433372 - (20{,}47/3600)$

$S' = 70{,}5223855$

Declination (δ)

$\sin\delta = \sin Q' \times \sin S'$

$\sin\delta = \sin(23{,}4382905) \times \sin(70{,}5223855)$

$\sin\delta = 0{,}374997994$

$\delta = sin^{-1}(0{,}374997994)$

$\delta = 22{,}02418887$

$\delta = 22° \, 1' \, 27{,}07''$

Upright Length (PT)

$\tan \mathrm{PT} = \cos Q' \times \tan S'$

$\tan \mathrm{PT} = \cos(23{,}4382905) \times \tan(70{,}5223855)$

$\tan \mathrm{PT} = 2{,}594129613$

$PT = tan^{-1}(2{,}594129613)$

$PT = 68{,}91905969$

Right ascension (RA)(α)

The right ascension value is calculated with the following conditions:

If S' is < 90 then α =PT

If S' is < 270 then α =PT +180

If S' is > 270 then α =PT +360

The value of S' on the above calculation is 70,5223855, therefore the value of right ascension is as follows:

$\alpha = \mathrm{PT} = 68{,}91905969$

Equation of Time (e)

$e = (S - \alpha)/15$

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$e = (69{,}47626228 - 68{,}91905969)/15$

$e = 0{,}037146839$

$e = 0^h 2^m 13{,}72^s$

Sun's Semi-diameter (SDM)

$SDM = 0{,}267/(1 - 0{,}017 \times \cos M)$

$SDM = 0{,}267/(1 - 0{,}017 \times \cos(146{,}1363116))$

$SDM = 0{,}263283434$

$SDM = 0° \, 15' \, 47{,}82''$

The approximate calculation above gives data with values that are not very different from the data in the Winhisab application. Below is a comparison of the data:

Table 2. Comparison of approximation data with Winhisab data

Ephemeris Data	Approximation Results	Winhisab Data
e	0^h 2^m $13{,}72^s$	0^h 2^m 13^s
δ	22^o 1' 27,07"	22^o 1' 25"
SDM	0^o 15' 47,82"	0^o 15' 46,47"

From the table 2 it can be seen that the value of the equation of time (e) calculated by the approximation method is within $0{,}72^s$dari data winhisab. Sedangkan nilaideklinasi Matahari (δ) hanya berselisih2,07" of the Winhisab data. While the value of the solar declination (δ) is only 2.07" away from the winhisab data. The difference in these data is very small, so when calculating the prayer time, the results may not be very different. In fact, there is a possibility that the results of the calculations will be the same, as prayer schedules generally only include the number of hours and minutes, without including the number of seconds.

Table 3 shows an excerpt of the prayer schedule calculated using the approximation data compared to the prayer schedule calculated using data from the winhisab application. The data presented is the schedule of prayer times in the city of Ternate for the period 1 May 2024 to 15 May 2024. This data covers only a small part of the data studied, as the full data can be

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downloaded from the following link:*https://bit.ly/aproximasi*

Disscussion

From the table 3, we can see that the prayer times calculated using the approximate data are not very different from the prayer times calculated using the Winhisab data. There are three different prayer times in the table above: Fajr prayer time for 9 May, Zuhr prayer time for 10 May and Maghrib prayer time for 1 May. It can also be seen that the difference in the prayer times produced is not more than one minute, this value is still smaller than the Ihtiyat time used in the calculation which is 2 minutes.

Table 3. Comparison of approximate prayer times with prayer times calculated using Winhisab data (Ternate City 1-15 May 2024)

Date	Subh		Dhuhr		Asr		Maghrib		Isha	
	A	B	A	B	A	B	A	B	A	B
1	5:05	5:05	12:29	12:29	15:50	15:50	18:33	18:34	19:45	19:45
2	5:05	5:05	12:29	12:29	15:50	15:50	18:33	18:33	19:45	19:45
3	5:05	5:05	12:29	12:29	15:50	15:50	18:33	18:33	19:45	19:45
4	5:05	5:05	12:29	12:29	15:50	15:50	18:33	18:33	19:45	19:45
5	5:04	5:04	12:29	12:29	15:50	15:50	18:33	18:33	19:45	19:45
6	5:04	5:04	12:29	12:29	15:50	15:50	18:33	18:33	19:45	19:45
7	5:04	5:04	12:29	12:29	15:51	15:51	18:33	18:33	19:45	19:45
8	5:04	5:04	12:29	12:29	15:51	15:51	18:33	18:33	19:45	19:45
9	5:03	5:04	12:29	12:29	15:51	15:51	18:33	18:33	19:45	19:45
10	5:03	5:03	12:28	12:29	15:51	15:51	18:33	18:33	19:45	19:45
11	5:03	5:03	12:28	12:28	15:51	15:51	18:33	18:33	19:45	19:45
12	5:03	5:03	12:28	12:28	15:51	15:51	18:33	18:33	19:46	19:46
13	5:03	5:03	12:28	12:28	15:52	15:52	18:33	18:33	19:46	19:46
14	5:03	5:03	12:28	12:28	15:52	15:52	18:33	18:33	19:46	19:46
15	5:03	5:03	12:28	12:28	15:52	15:52	18:33	18:33	19:46	19:46

Description:

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A = Prayer schedule calculated using approximate data

B = Prayer schedule calculated using data from Winhisab

The following are the results of the calculation of the accuracy of the prayer time schedule for each city used as a sample in this study:

Table 4. Accuracy of the prayer schedule for each city

City	Different Data (From 1830)	Accuracy(%)
Ambon	39	97,87
Tual	35	98,09
Ternate	38	97,92
Tidore	40	97,81
Sofifi	40	97,81
Merauke	50	97,27
Jayapura	36	98,03
Raja Apat	39	97,87
Manokwari	46	97,49
Sorong	33	98,20
Average	**39,6**	**97,84**

From the table 4, we can see that the average accuracy of the prayer schedule calculated using the approximated data is 97.84%. The average number of discrepancies is 39.6. This value is quite small when compared to the amount of prayer time data calculated for one year, which is 1830 data.

In this study, the prayer schedule with the highest accuracy was obtained for the city of Sorong with 33 data discrepancies and an accuracy of 98.20%. While the prayer schedule with the lowest accuracy is for the city of Merauke with 50 data differences and an accuracy of 97.27%.If the data is disaggregated for each prayer time, the following data is obtained:

From the table 5it can be seen that the distribution of the data tends to be random and there is no particular pattern. There is no one prayer time that is more or less accurate than the others.The accuracy for each prayer time ranges from 97% to 98%. The lowest accuracy is for the Fajr prayer time in the city of Tidore with 13 data differences and an accuracy of 96.45%. While the highest accuracy is for the Maghrib prayer time in Sorong city with 3 data differences and an accuracy of 99.18%.

Table 5. Breakdown of data accuracy for each prayer time

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City	Subh		Dhuhr		Asr		Maghrib		Isha	
	Difference	Accuracy (%)	Difference	Accuracy (%)	Difference	Accuracy (%)	Difference	Accuracy (%)	Difference	Accuracy (%)
Ambon	12	96,72	3	99,18	8	97,81	9	97,54	7	98,09
Tual	8	97,81	5	98,63	5	98,63	10	97,27	7	98,09
Ternate	8	97,81	8	97,81	9	97,54	9	97,54	4	98,91
Tidore	13	96,45	5	98,63	6	98,36	12	96,72	4	98,91
Sofifi	10	97,27	9	97,54	7	98,09	10	97,27	4	98,91
Merauke	6	98,36	9	97,54	12	96,72	12	96,72	11	96,99
Jayapura	4	98,91	10	97,27	5	98,63	6	98,36	11	96,99
Raja Ampat	6	98,36	10	97,27	12	96,72	4	98,91	7	98,09
Manokwari	9	97,54	9	97,54	11	96,99	8	97,81	9	97,54
Sorong	5	98,63	7	98,09	10	97,27	3	99,18	8	97,81
Average	**8,1**	**97,79**	**7,5**	**97,95**	**8,5**	**97,68**	**8,3**	**97,73**	**7,2**	**98,03**

D. Conclusion

The following conclusions can be drawn from this research, namely 1) Epimeris data including equation of time (e), solar declination (δ), and solar semidiameter (SDM) can be calculated using the approximation method; 2) The data from the approximation has a value that is not much different when compared to the data from the Winhisab application; 3) The prayer schedule calculated using the approximation data has an accuracy of more than 97% when compared to the prayer schedule calculated using the winhisab data. 4) The different prayer time data have a difference of +1 minute.The value of this data difference is still smaller than the ihtiyat time used in the calculation, which is 2 minutes.For these reasons, the prayer time schedule calculated using the approximation data can be categorised as a fairly accurate prayer time schedule.

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