Contribution Title Monthly Cumulative Periodic Modeling of Rainfall Using TRMM and CHIRPS Rainfall Data

A. Ashruri[1*], S. Tugiono[1], A. Zakaria[1], A.D. Putra[1], D. Mardhatila[1], E.S. Adha[1]

Department of Civil Engineering, Engineering Faculty, Lampung University, Indonesia
*ashruri.1987@eng.unila.ac.id

Abstract. For engineering planning, especially water structures such as irrigation, dams, urban drainage, ports, docks, etc., rainfall data is very important. Rainfall has a periodic nature, because it is affected by climates such as wind, temperature, humidity and so on. These parameters are transferred into periodic components. Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a collection of rainfall data from 1981 to the present, CHIRPS combines internal climatology, CHPclim, 0.05° resolution satellite imagery, and in-situ station data to create a rainfall time series rainfall, trend analysis and seasonal drought monitoring. Meanwhile, the Tropical Rainfall Measuring Mission (TRMM) is a joint space mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. TRMM and CHIRPS rain data will then be used in this research. The methodology used is periodic modeling. The harmonic component P(t) relates to a displacement that oscillates for a particular interval. The existence of P(t) is identified using the FFT. The results of the calculations that have been carried out, the author draws the conclusion that the Average Correlation Coefficient (R) for the CHIRPS data obtained, namely in the Periodic Model, is 0.9813, while for the TRMM data obtained it is 0.9775.

Keywords: Periodic, TRMM, CHIRPS

1 Introduction

1.1 A Subsection Sample

Rain is an event of precipitation (liquid falling from the atmosphere in liquid or frozen form onto the earth's surface) in the form of liquid. Rain requires the presence of a thick layer of atmosphere in order to find temperatures above the melting point of ice on the Earth's surface [1]. Rain has periodic and stochastic properties, because it is influenced by climate parameters such as air temperature, wind direction, humidity and so on, which are also periodic and stochastic. These parameters are transferred into periodic and stochastic components. Furthermore, rainfall can be calculated both the periodic component and the stochastic component. Determine all known factors and assume that rainfall or precipitation is a function of periodic and stochastic variations

A. Zakaria et al. (eds.), *Proceedings of the 1st International Conference on Industry Science Technology and Sustainability (IConISTS 2023)*, Advances in Engineering Research 235,
https://doi.org/10.2991/978-94-6463-475-4_10

of climate. With periodic and stochastic analysis of the time series, a model will be produced that will calculate the periodic and stochastic parts to be used to predict daily rainfall variations in the future [2].

Rainfall is one of the weather parameters whose data is very important to obtain for the benefit of BMG and the community who need rainfall data. Rain has a huge influence on human life, because it can facilitate or even hinder human activities. Therefore, the quality of the rainfall data obtained must be of high quality and have high accuracy. So an observer must know the rain measuring equipment used at the observation station properly. One of the rain gauges that is often used is the Hellman type rain gauge [3].

Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a collection of rainfall data from 1981 to the present, CHIRPS combines internal climatology, CHPclim, 0.05° resolution satellite imagery, and in-situ station data to create a rainfall time series rainfall, trend analysis and seasonal drought monitoring [4] [5]. Meanwhile, the Tropical Rainfall Measuring Mission (TRMM) is a joint space mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. TRMM and CHIRPS rain data will then be used in this research.

2 Methodology

2.1 Research Location and Time

The study area of this research is the Radin Inten II Meteorological Station area, Latitude -5.16000, Longitude 105.11000, Elevation 85 m DPL. This area is one of the locations in South Lampung Regency, Lampung Province, Indonesia.

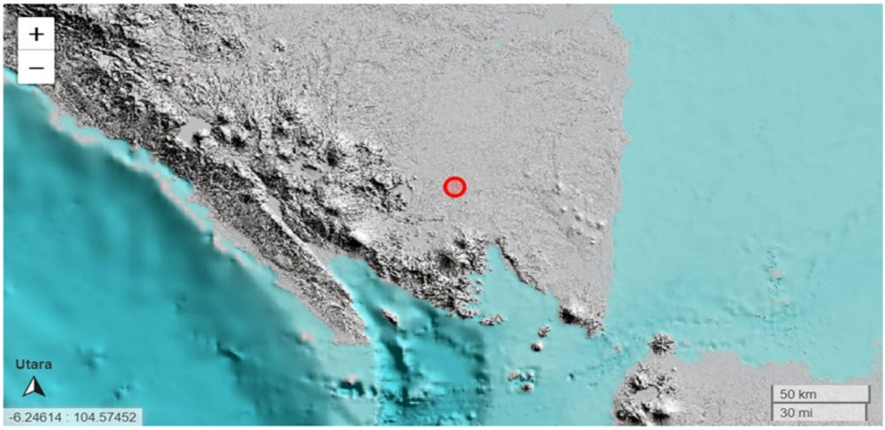


Fig. 1. Map of research location.

2.2 Periodic and Spectrum Method

Time series data can be decomposed into deterministic components which can be formulated into values in the form of components which are exact solutions and stochastic components, where these values are always presented as a function consisting of several time series data functions. Xtr time series data is presented as a model consisting of several functions as follows [6-8]. Displayed equations are centered and set on a separate line.

$$X_t = T_t + P_t + S_t \tag{1}$$

The trend component describes changes in the length of long rainfall data recordings during rainfall data recording, and ignores fluctuation components with short durations. In this research, the rain data used is estimated to have no trend. So this equation can be presented as follows:

$$X_t \approx P_t + S_t \tag{2}$$

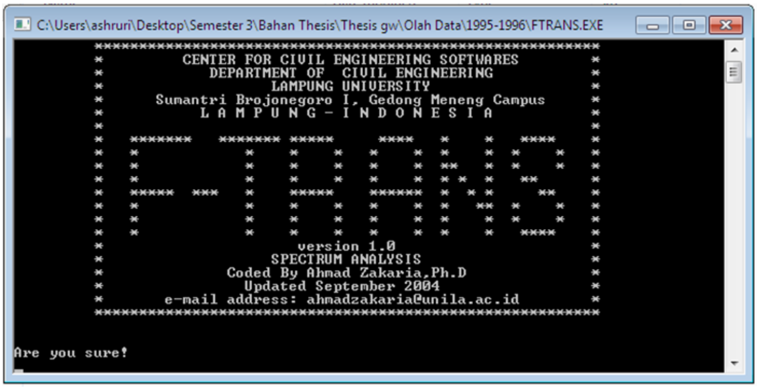
The spectrum method is a transformation method that is generally used in many applications. This method can be represented as a Fourier Transform equation as follows [8-9]

$$\mathrm{P}(\mathrm{f_m}) = \frac{\Delta \mathrm{t}}{2\sqrt{\pi}} \sum_{-\mathrm{N}/2}^{\mathrm{n}=\mathrm{N}/2} \mathrm{P}(\mathrm{t_n}).\,\mathrm{e}^{\frac{-2.\pi.\mathrm{i}}{\mathrm{M}}.\mathrm{m}.\mathrm{n}} \tag{3}$$

Where $P(_{tn})$ is the rainfall series data in the time domain and $P(f_n)$ is the rainfall series data in the frequency domain. t_n is a time series variable that represents the Nth data length, f_m is a frequency series variable. Based on the rainfall frequency resulting from Equation (3), the amplitude as a function of rainfall frequency can be generated. The maximum amplitude can be determined from the amplitude of the resulting amplitude as the significant amplitude. Rainfall frequencies of significant amplitude are used to simulate synthetic or artificial daily rainfall which is assumed to be a significant rainfall frequency. The frequency of significant rainfall produced in this study is used to calculate the angular frequency and determine the periodic component of daily rainfall using Equation (3).

In mathematics, a nearly periodic function is a function of real numbers that is periodic to any desired degree of accuracy because its "near period" is long and well distributed. This concept was originally researched by Harald Bohr, then simplified by Vyacheslav Stepanov, Hermann Weyl, and Abram Samoilovitch Besicovitch. There are also nearly periodic functions in closed compact abelian groups that were first investigated by John von Neumann. Almost periodicity is the property of a dynamical system that appears to retrace its path through phase space, but is not completely precise.

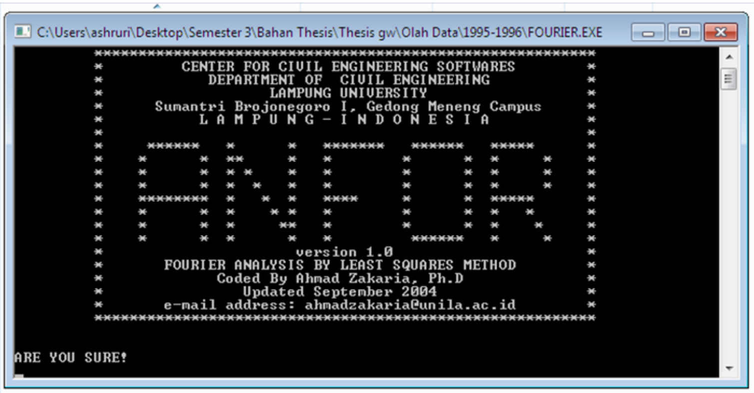
The periodic component P(t) relates to a displacement that oscillates for a certain interval [10]. The existence of P(t) is identified using the Fourier Transformation method. The oscillating part indicates the existence of P(t), using the period P, several peak periods can be estimated using Fourier analysis.



```
         *********************************************************
         *         CENTER FOR CIVIL ENGINEERING SOFTWARES        *
         *            DEPARTMENT OF  CIVIL ENGINEERING           *
         *                   LAMPUNG UNIVERSITY                  *
         *      Sumantri Brojonegoro I, Gedong Meneng Campus     *
         *           L A M P U N G - I N D O N E S I A           *
         *                                                       *
         *   *******   ******* *****     ****   *    *   ****    *
         *   *            *    *    *   *    *  *    *  *    *   *
         *   *            *    *    *   *    *  **   *  *    *   *
         *   *            *    *    *   *    *  * *  *   **      *
         *   *****  ***   *    *****    ******  *  * *     **    *
         *   *            *    *    *   *    *  *   **  *    *   *
         *   *            *    *    *   *    *  *    *  *    *   *
         *   *            *    *    *   *    *  *    *   ****    *
         *                      version 1.0                      *
         *                   SPECTRUM ANALYSIS                   *
         *              Coded By Ahmad Zakaria,Ph.D              *
         *                Updated September 2004                 *
         *       e-mail address: ahmadzakaria@unila.ac.id        *
         *********************************************************

Are you sure!
```

Fig. 2. Fast Fourier transform program.



```
         *********************************************************
         *         CENTER FOR CIVIL ENGINEERING SOFTWARES        *
         *            DEPARTMENT OF  CIVIL ENGINEERING           *
         *                   LAMPUNG UNIVERSITY                  *
         *      Sumantri Brojonegoro I, Gedong Meneng Campus     *
         *           L A M P U N G - I N D O N E S I A           *
         *                                                       *
         *     ******   *      *   *******   ******   *****      *
         *    *      *  **     *   *        *      *  *     *    *
         *    *      *  * *    *   *        *      *  *     *    *
         *    *      *  *  *   *   *        *      *  *     *    *
         *    ********  *   *  *   ****     *      *  *****      *
         *    *      *  *    * *   *        *      *  *   *      *
         *    *      *  *     **   *        *      *  *    *     *
         *    *      *  *      *   *         ******   *     *    *
         *                      version 1.0                      *
         *       FOURIER ANALYSIS BY LEAST SQUARES METHOD        *
         *             Coded By Ahmad Zakaria, Ph.D              *
         *                Updated September 2004                 *
         *       e-mail address: ahmadzakaria@unila.ac.id        *
         *********************************************************

ARE YOU SURE!
```

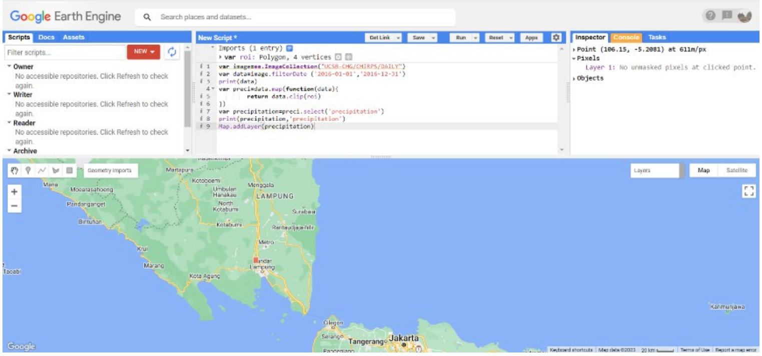
Fig. 3. Fourier program.

The frequencies obtained from the spectral method clearly show periodic variations. The periodic component $P(f_m)$ can also be written in terms of the angular frequency ωr. Next, an equation can be expressed in Fourier form as follows [11].

$$\hat{P}(\mathrm{t}) = S_o + \sum_{r=1}^{r=k} A_r \sin(\omega_r . t) + \sum_{r=1}^{r=k} B_r \cos(\omega_r . t) \tag{3}$$

2.3 Data Collection

Daily rainfall data is taken from TRMM and CHIRPS Lampung Province. The rain data used for this study covers a 10-year period (2010-2019). The mathematical procedures taken to formulate the predicted model are discussed next. The most principal objective of this analysis is to determine a realistic model to calculate and decompose time series rainfall data into various components of varying frequency, amplitude and rain phase.



Owner
No accessible repositories. Click Refresh to check again.
Writer
No accessible repositories. Click Refresh to check again.
Reader
No accessible repositories. Click Refresh to check again.
Archive

```
Imports (1 entry)
  var roi: Polygon, 4 vertices
var image=ee.ImageCollection("UCSB-CHG/CHIRPS/DAILY")
var data=image.filterDate ('2016-01-01','2016-12-31')
print(data)
var preci=data.map(function(data){
        return data.clip(roi)
})
var precipitation=preci.select('precipitation')
print(precipitation,'precipitation')
Map.addLayer(precipitation)
```

```
Point (106.15, -5.2081) at 611m/px
Pixels
   Layer 1: No unmasked pixels at clicked point.
Objects
```

Fig. 4. CHIRPS rainfall data.

2.4 Model Calibration

Sinus. What must be done is as follows [12]: The data used was 512 data (Sine 0 to Sine 512). Save the data into a file named signals.inp (signal input). Converting serial daily bulk data into spectrum data using the FFT (Fast Fourier Transform) program. Calculating periodic components using the Fourier transformation method. The files used to run the Fourier program are the signals.inp (signal input) and fourier.inp (Fourier input) files.

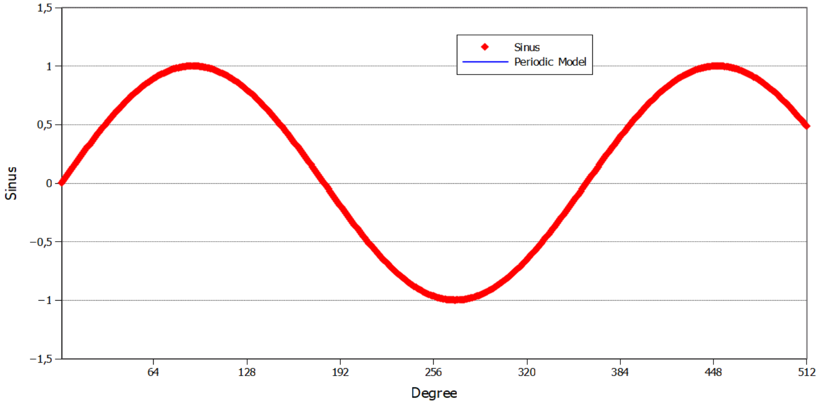


Fig. 5. Periodic model data sinus (512 data).

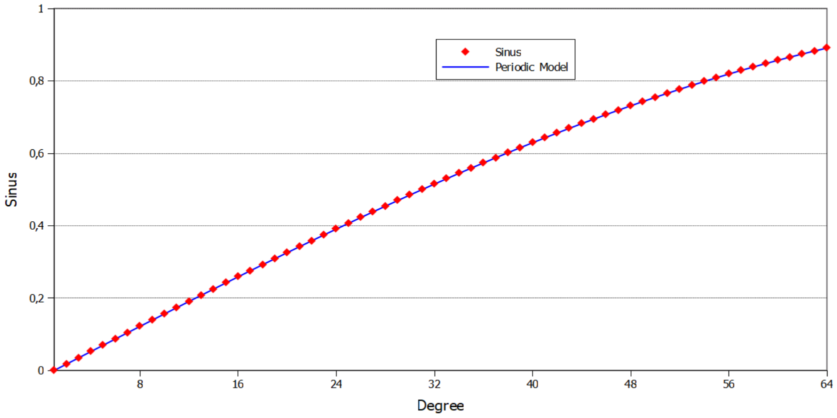


Fig. 6. Periodic model data sinus (64 data).

Cosinus. What must be done is as follows [10]: The data used was 512 data (Sine 0 to Sine 512). Save the data into a file named signals.inp (signal input). Converting serial daily bulk data into spectrum data using the FFT (Fast Fourier Transform) program. Calculating periodic components using the fourier transformation method. The files used to run the Fourier program are the signals.inp (signal input) and fourier.inp (fourier input) files.

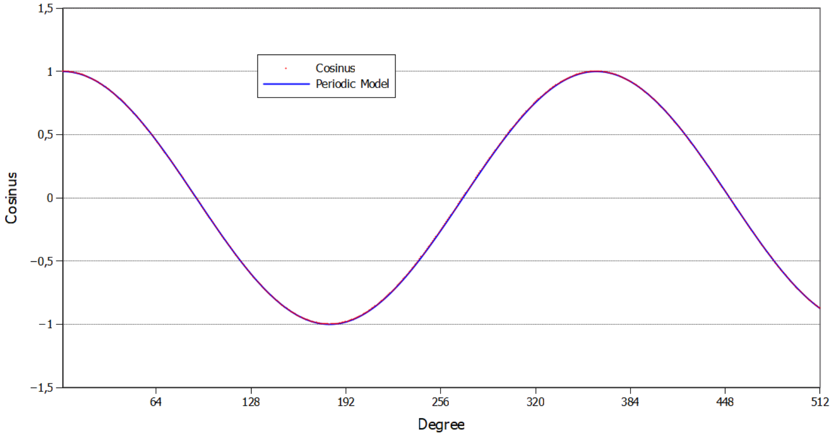


Fig. 7. Periodic model data cosines (512 data).

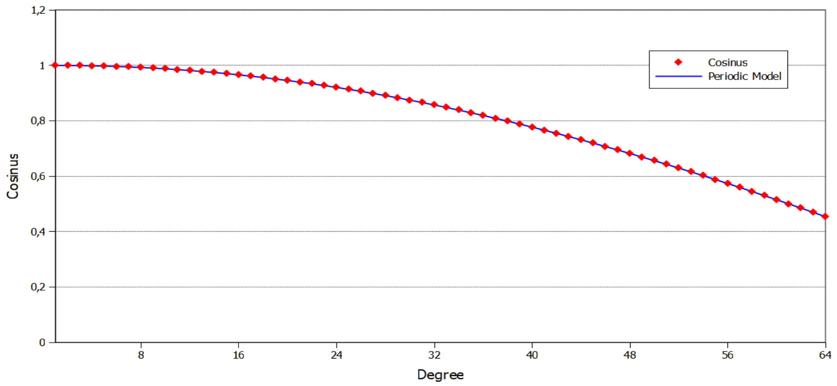


Fig. 8. Periodic model data cosines (64 data).

3 Results and Discussions

3.1 Rainfall Data Modelling

Daily Rainfall Data. To determine the periodic characteristics of daily rainfall in this study, CHIRPS and TRMM data from the 10-year time series (2010-2019) at the *Radin Inten II* Meteorological Rain Station were used. Time series data from over 10 years is shown in the following figures.

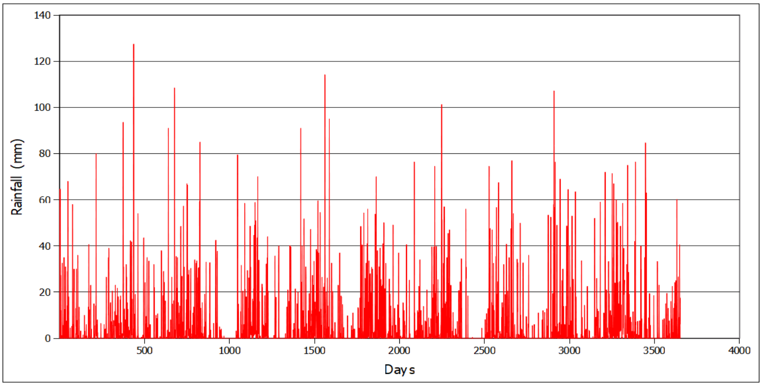


Fig. 9. CHIRPS rainfall time series for 10 years from *Radin Inten II* rain station.

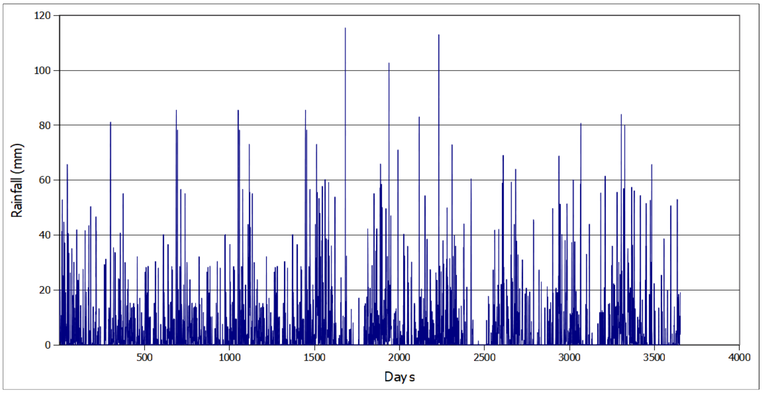


Fig.10. TRMM rainfall time series for 10 years from Radin Inten II rain station.

To run the FFT (Fast Fourier Transform) program you need a file with the.inp (input) extension called signal.inp. To model 1 year of rainfall data, this file requires a data length of 512 days, so 365 days in the first year plus 147 days in the second year. The data is sorted from the first day of the first year to the 147th day of the second year and saved into a file called signal.inp. Time series data from 2010 and 2010 are shown in the following figure:

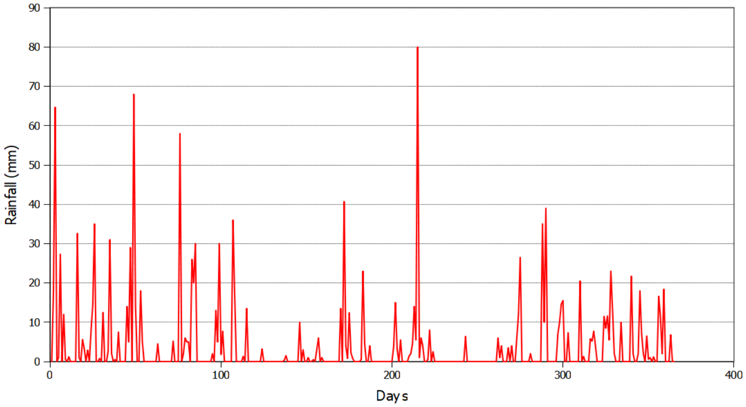


Fig.11. CHIRPS time series rainfall in 2010 from the Radin Inten II meteorological rain station.

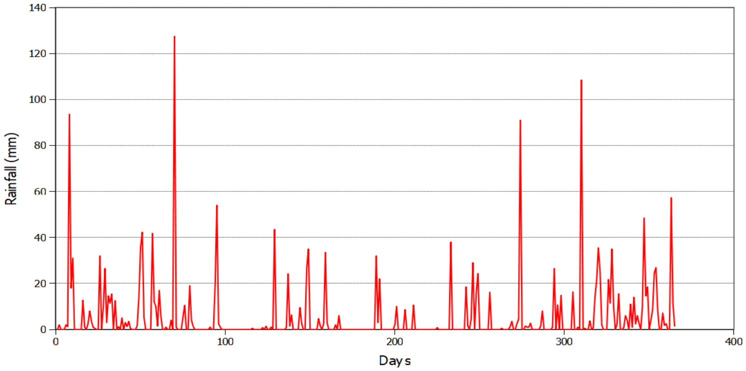


Fig.12. CHIRPS time series rainfall in 2011 from the Radin Inten II meteorological rain station.

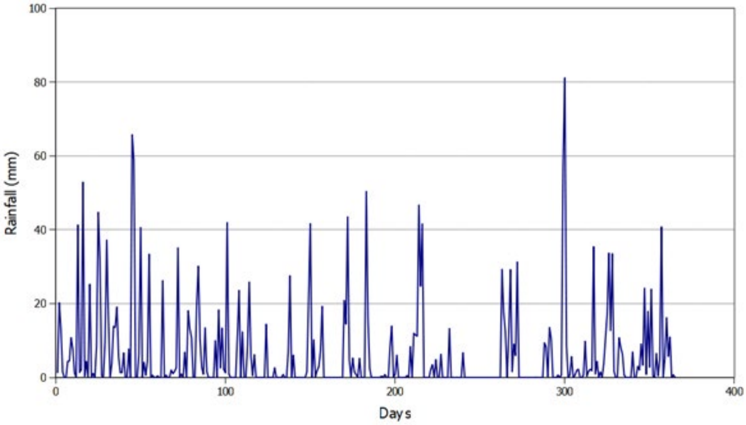


Fig.13. TRMM Time series rainfall in 2010 from the Radin Inten II meteorological rain station.

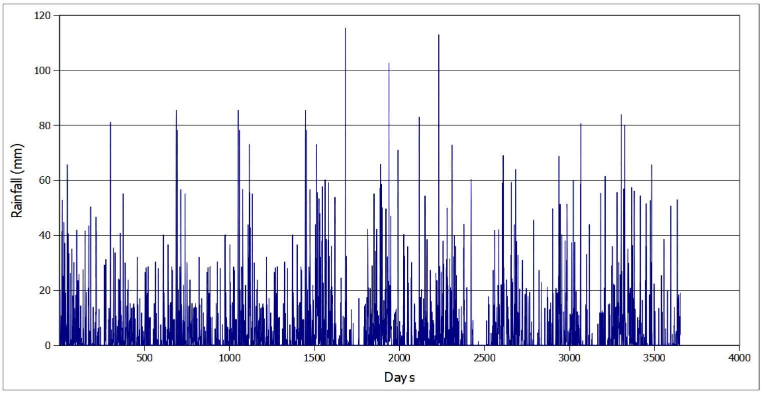


Fig.14. TRMM Time series rainfall in 2011 from the Radin Inten II meteorological rain station.

Daily Rainfall Spectrum. After the file named signal.inp has been created, we run the FFT (Fast Fourier Transform) program. Based on the time series rainfall, a spectrum of time series daily rainfall data was generated using the FFT (Fast Fourier Transform) method. The spectrum of time series daily rainfall data from rain stations is presented in the following figure.

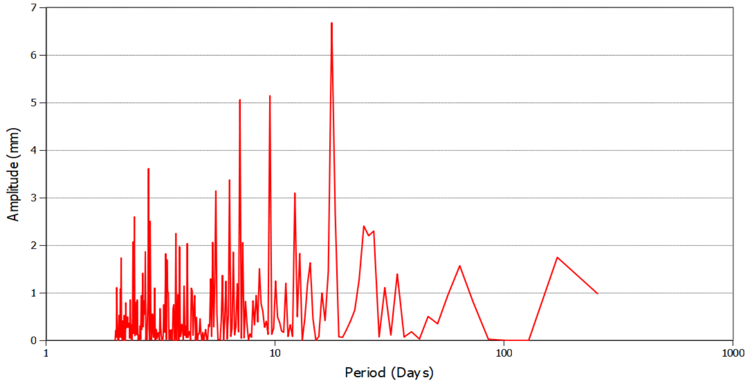


Fig.15. Time Series CHIRPS Rainfall Spectrum in 2010 from the Radin Inten II meteorological rain station.

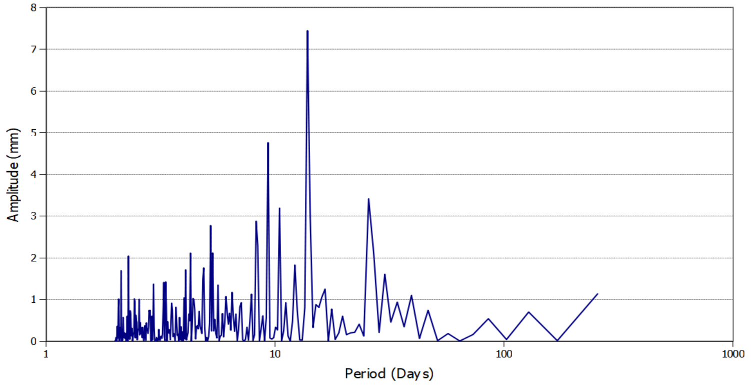


Fig.16. Time Series CHIRPS Rainfall Spectrum in 2011 from the Radin Inten II meteorological rain station.

After running the FFT (Fast Fourier Transform) program it will produce 3 files, namely:

1. Spectrum.eps
2. Spectrum.out (used to draw a rainfall spectrum graph)
3. Fourier.inp (used as input to run the next program, namely the Fourier Program)

Daily Rainfall Spectrum. The Periodic Model component of time series rainfall is calculated using the Fourier Transform Method to produce periodic rainfall frequencies. Just like the previous program to model 1 year of rainfall data, this file requires a data length of 512 days, so 365 days in the first year plus 147 days in the second year. The files needed to run the Fourier program are the signals.inp (signal input) and fourier.inp (fourier input generated by the FFT / Fast Fourier Transform) files.

To show the difference between the periodic model and rain data, the author displays a graph with a data length of 64 days taken randomly from the research data length of 512 days so that the difference can be seen clearly. A comparison graph between rainfall data and the periodic model is presented in the following figure:

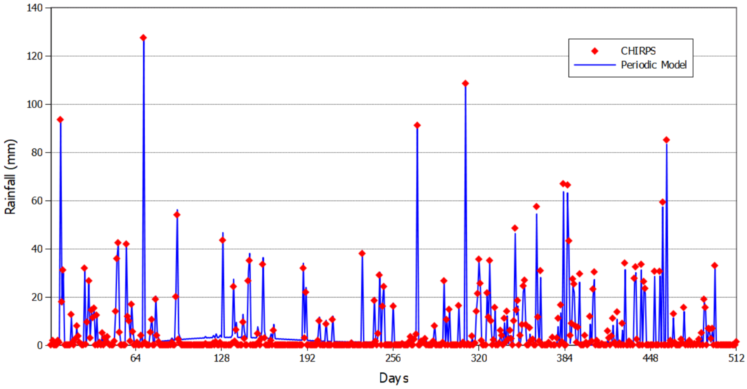


Fig.17. Periodic model of daily CHIRPS rainfall in 2010 from the Radin Inten II meteorological rain station (512 days).

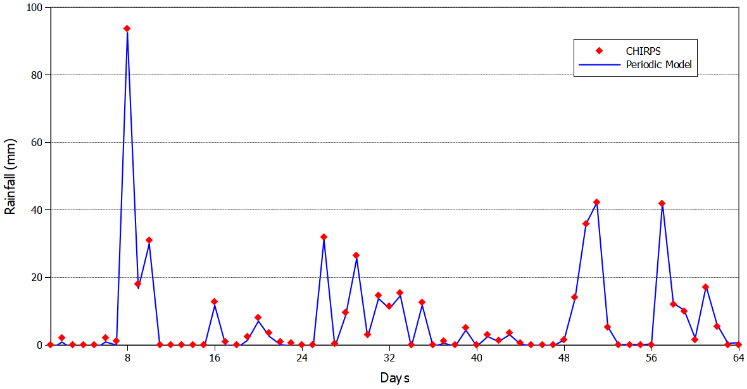


Fig.18. Periodic model of daily CHIRPS rainfall in 2010 from the Radin Inten II meteorological rain station (64 days).

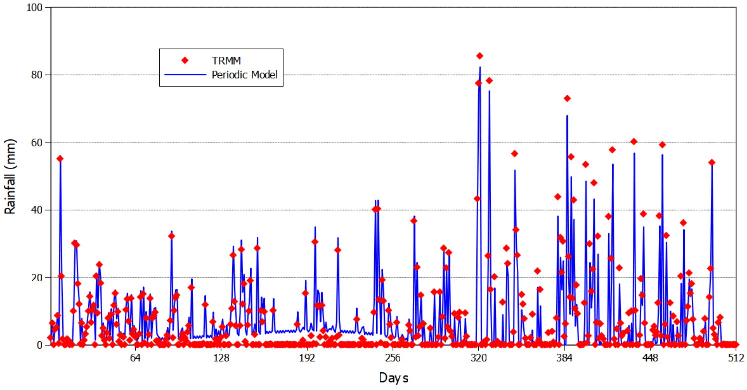


Fig.19. Periodic model of daily TRMM rainfall in 2010 from the Radin Inten II meteorological rain station (512 days).

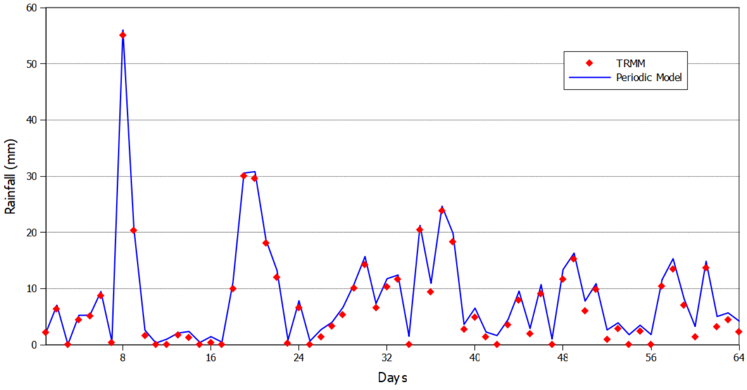


Fig. 20. Periodic model of daily TRMM rainfall in 2010 from the Radin Inten II meteorological rain station (64 days).

The periodic model has characteristics like the input data, namely the rainfall spectrum. The daily rainfall data and the periodic model only have a small difference.

3.2 Rainfall Data Modelling

To see the accuracy between the Measured Rain Data and the Modeling carried out, we calculate the Correlation Coefficient (R) between the Measured Rain Data and Periodic Modeling.

Table 1. Correlation coefficient (R) periodic model from Radin Inten II. (CHIRPS).

No.	Year	Correlation
1.	2010	0.98951213287273
2.	2011	0.98983687850388
3.	2012	0.97238593006047
4.	2013	0.98026618158737
5.	2014	0.98501606603968
6.	2015	0.98435173666880
7.	2016	0.97121919797793
8.	2017	0.99139595987634
9.	2018	0.97220908003217
10.	2019	0.97682049014944

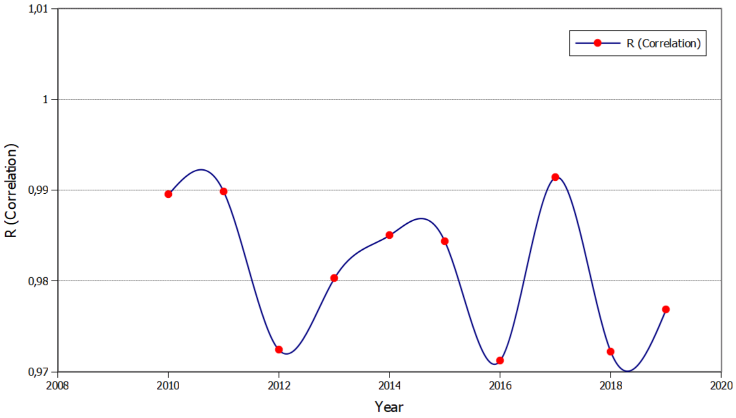


Fig. 21. Correlation coefficient (R) periodic model from Radin Inten II. (CHIRPS).

Table 2. Correlation coefficient (R) periodic model from Radin Inten II (TRMM).

No	Year	Correlation
1.	2010	0.99003850016485
2.	2011	0.96846157998733
3.	2012	0.96736603991492
4.	2013	0.96846157998733
5.	2014	0.97310985252516
6.	2015	0.98710859090302
7.	2016	0.9714739003151
8.	2017	0.98877018543465
9.	2018	0.98447760261353
10.	2019	0.9765091185616

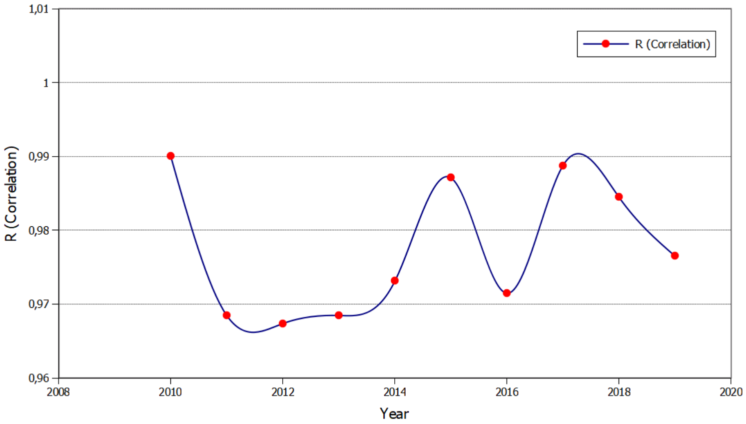


Fig. 22. Correlation coefficient (R) periodic model from Radin Inten II. (TRMM).

From Table 1 we can see that the Correlation Coefficient (R) of the Periodic Model is close to the Measured Rain Data. This shows that the modeling produced by the FFT (Fast Fourier Transform) Program, and the Fourier Program is quite good for modeling the rain data itself. From table 1 we can see that the Correlation Coefficient (R) of the Periodic Model is close to the Measured Rain Data. This shows that the modeling produced by the Auto Regressive Program is quite good for modeling the rain data itself.

3.3 Monthly Cumulative Rainfall

The calculation results from periodic modeling are presented in monthly cumulative terms in the following tables and graphs:

Table 3. Comparison of the monthly cumulative rainfall and periodic models in 2010 from the CHIRPS rain station.

No.	Month	Rainfall	Model
1.	Jan	341.3	336.333439533248
2.	Feb	287.8	290.470751516261
3.	Mar	197.4	202.312155057031
4.	Apr	184.0	186.408183892706
5.	May	133.2	131.673360709774
6.	Jun	127.4	124.746674960104
7.	Jul	142.6	142.681993798581
8.	Aug	149.6	153.048050823466
9.	Sep	147.6	150.743722966163
10.	Oct	196.4	195.755545502159
11.	Nov	202.5	198.518983962733
12.	Dec	185.6	182.340151393785

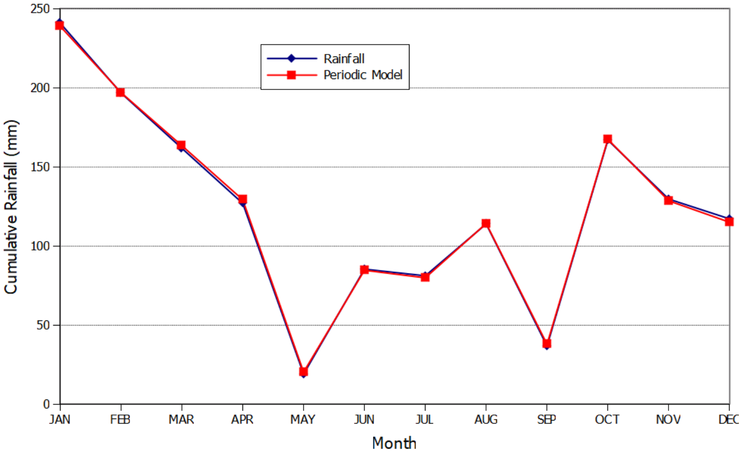


Fig. 23. Comparison of the monthly cumulative rainfall and periodic models in 2010 from the CHIRPS rain station.

Table 4. Comparison of the monthly cumulative rainfall and periodic models in 2010 from the TRMM rain station.

No.	Month	Rainfall	Model
1.	Jan	341.3	336.333439533248
2.	Feb	287.8	290.470751516261
3.	Mar	197.4	202.312155057031
4.	Apr	184.0	186.408183892706
5.	May	133.2	131.673360709774
6.	Jun	127.4	124.746674960104
7.	Jul	142.6	142.681993798581
8.	Aug	149.6	153.048050823466
9.	Sep	147.6	150.743722966163
10.	Oct	196.4	195.755545502159
11.	Nov	202.5	198.518983962733
12.	Dec	185.6	182.340151393785

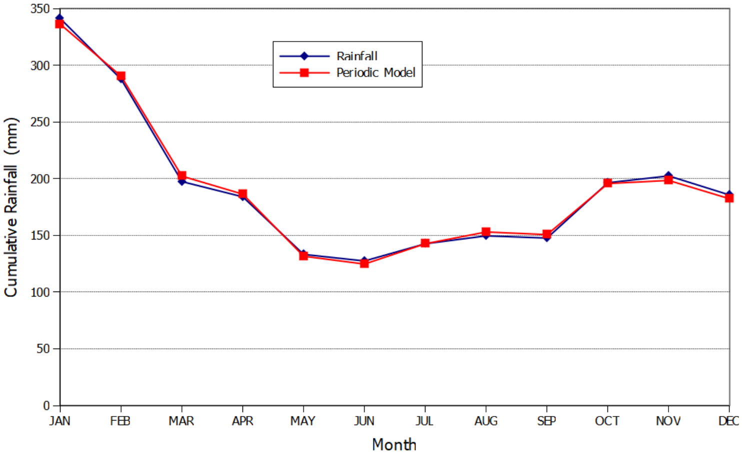


Fig. 24. Comparison of the monthly cumulative rainfall and periodic models in 2010 from the CHIRPS rain station.

4 Conclusion

The results of the calculations that have been carried out, the author draws the conclusion that the Average Correlation Coefficient (R) for the CHIRPS data obtained, namely in the Periodic Model, is 0.9813, while for the TRMM data obtained it is 0.9775. This shows that the modelling produced by the FFT (Fast Fourier Transform) Program and the Fourier Program is quite good for modelling the rain data itself.

Acknowledgments. A third level heading in 9-point font size at the end of the paper is used for general acknowledgments, for example: This study was funded by X (grant number Y).

References

1. Triadmojo, B.: Applied Hydrology. Beta Offset, Yogyakarta (2008)
2. Zakaria, A.: Stochastic modeling study of daily rainfall from Purajaya station rainfall data. In: National Seminar on Natural Science and its Applications, pp. 145-155. Lampung University (2010)
3. Bunganaen, W.: Analysis of the Relationship between Rain Thickness and Rain Duration at the Lasiana Climatology Station Kupang City. Journal of Civil Engineering 2(2), 182-183 (2013)
4. Misnawati: Comparison of Bias Correction Methodologies for Chirps Rainfall Data. Limnotek 25(1), 18-29 (2018)
5. Solehawati, M.: Utilization of Chirps Data for Mapping Meteorological Drought Using the Standardized Precipitation Index (Spi) on the Island of Java. Universitas Gadjah Mada (2019)

6. Rizalihadi, M.: The generation of synthetic sequences of monthly rainfall using autoregressive model. Journal of Civil Engineering University Syah Kuala 1(2), 64-68 (2002)
7. Bhakar, S.R., Singh, V.R., Chhajed, N., Bansal, Kumar, A.: Stochastic modeling of monthly rainfall at kota region. ARPN Journal of Engineering and Applied Sciences 1(3), 36-44 (2006)
8. Zakaria, A.: The Generation of Synthetic Sequences of Monthly Cumulative Rainfall using FFT and Least Square Method. In: Proceedings of the Seminar on Research Results & Community Service University of Lampung, vol. 1, pp. 1-15 (2008)
9. Zakaria, A.: Numerical Modelling of Wave Propagation using Higher Order Finite Difference Formulas, Ph.D. Thesis, Curtin University of Technology, Perth W.A., Australia (2003)
10. Kottegoda, N.T.: Stochastic Water Resources Technology. The Macmillan Press Ltd., London (1980)
11. Zakaria, A.: Preliminary Study of Tidal Prediction using Least Squares Method, Master's Thesis, Bandung Institute of Technology, Bandung, Indonesia (1998)
12. Ashruri: Periodic and Stochastic Modeling to Analyze Missing Rainfall Using the Sukarame Rain Station Case Study. Engineering Journal 19(1) (2015)