Combination of flood models with weather research and forecast based on extreme rainfall for hazard mitigations

R Gernowo, C E Widodo, A A Yatunnisa, H Kurrotaa’yun
Department of Physics, Faculty of Science and Mathematics, Diponegoro University Jl. Prof. Soedarto, SH., Tembalang Semarang 50275, Indonesia

Corresponding author: gernowo@yahoo.com

Abstract. Semarang city in central java Indonesia has a strategic location as the capital of Central Java Province and developed into the fifth largest metropolitan city in Indonesia. The city of Semarang, which is traversed by the north coast route (pantura) is often flooded during the rainy season. This is because the intensity of rainfall is high and some areas in the city of Semarang are rob areas so that when there is a tide of sea water this area will be flooded. The combination of the Flood model and the weather prediction model will illustrate future conditions. The results showed that the prediction of flood distribution based on rainfall for a period of 10 years. With the flood model the period pattern of rainfall intensity values obtained is processed into a relationship graph between the duration of rain in minutes with the intensity of rain in the return period of 2 years, 5 years, 10 years and 25 years. The rainfall intensity value obtained will then be used to determine the peak discharge value

1. Introduction
Natural disasters now often occur in Indonesia, especially in terms of atmospheric anomalies. The aircraft accidents are caused by extreme convective cloud growing in other name the Cumulonimbus (Cb) clouds[1,2].Semarang city has a strategic location as the capital of Central Java Province and developed into the fifth largest metropolitan city in Indonesia. The city of Semarang, which is traversed by the north coast route (pantura) is often flooded during the rainy season. This is because the intensity of rainfall is high and some areas in the city of Semarang are rob areas so that when there is a tide of sea water this area will be flooded[2].

Flood mitigation is needed, at least to minimize losses caused by flooding in the form of intensive treatment in river watersheds in the form of planting trees for water absorption and also preventive treatment in the form of avoiding or alerting to flooding early on. Model studies will be conducted to determine the predicted spread of floods in the Semarang City area using the WRF model and the Flood Model to calculate the predicted results from the peak discharge of the City of Semarang in the return period of 2 years, 5 years and 10 years to 25 years in the future[3,4].

2. Methods

2.1. WRF model analysis method
The FNL data analysis is operational data from the National Centers for Environmental Prediction (NCEP). FNL provides data with a global system. The FNL collected observational data
approximately six hours ago synoptic observations and then made a global analysis and 3, 6 and 9 hour predictions, the FNL was run at high resolution [5][6].

2.2. Data needed in this research are:
Satellite data (GSMaP). Global Satellite Mapping of Precipitation (GSMaP) is rainfall measurement data using space satellite media.[10] [11]

2.3. BMKG data
Rainfall data for a period of 10 years in the Semarang area, as secondary data for model calculations.

2.4. Flood model
The study was conducted by determining the area of influence of the rain station on the area of the study area using the Polygon Thiessen method, hydrological analysis to obtain the value of rainfall intensity with the Mononobe method, calculation of peak discharge with a dynamic system, and modelling the predictions of flood distribution. Hydrological analysis is carried out to obtain the hydrological and meteorological characteristics of the Watershed. The aim is to determine the flow rate, so it can be used to determine the potential distribution of floods. Hydrological analysis is done by determining the rainfall in the area using the Polygon Thiessen formula as follows:

$$\bar{R} = \frac{A_1 R_1 + A_2 R_2 + \cdots + A_n R_n}{A_1 + A_2 + \cdots + A_n}$$ (1)

\(\bar{R}\) is the average rainfall, \(A_i\), \(A_j\), \(A_k\) is the area of influence of each rain station \(R_1\), \(R_2\), \(R_3\) is the rainfall at each rain station and \(n\) is the number of rain stations [13]

The next process in hydrological analysis is frequency analysis which uses probability distribution theory of probability distribution and one of which is commonly used is the distribution of Log Pearson type III with the following formula [13].

$$Y = \bar{Y} + k S$$ (2)

To determine the Design Flood Discharge, it is necessary to obtain the value of a Rainfall Intensity especially when the rational method is used. Rainfall intensity is the height of rainfall that occurs at a certain time when the water concentrates. Analysis of rainfall intensity can be processed from rainfall data that has occurred in the past [14].

To calculate the intensity of rainfall one empirical formula can be used according to Dr. Mononobe is used when rainfall data are available only daily rainfall [13].

$$I = \frac{R_{24}}{24} \left( \frac{24}{t} \right)^{2/3}$$ (3)

\(I\) is the intensity of rainfall, \(R_{24}\) is the maximum rainfall in 24 hours and \(t\) is the time or duration of rainfall.

After obtaining the value of rain intensity, one method that is often used to estimate the peak surface flow rate is the Rational method. The formula to calculate the flood plan discharge using the Rational method is as follows [15]:

$$Q_p = \frac{C \cdot I \cdot A}{3.6} = 0.278 C \cdot I \cdot A$$ (4)

\(Q_p\) is the peak surface flow rate (discharge), \(C\) is the runoff or runoff coefficient, \(I\) is the rainfall intensity, \(A\) is the exposed area.

3. Results and discussion
After processing the data on daily rainfall data from BMKG and FNL data, the results of four rainfall models from WRF (Weather Research and Forecasting) are obtained. The results of the four rainfall
models are shown in Figure 1, Figure 2, Figure 3 and Figure 4. The four rainfall models illustrate the rainfall in the city of Semarang with a ratio or multiples of once every 6 hours [7].

Figure 1. 06z Rainfall model results from WRF

In the 06z Rainfall or at 06.00 West Indonesia Time on January 15, 2013 seen in Figure 1. The 06z Rainfall Model results from WRF (Weather Research and Forecasting), illustrate moderate rainfall. Because of the results of this model the position of rainfall is still in the sea area of the city of Semarang [8].

Figure 2. Results of the 12z Rainfall Model from WRF
While on Rainfall 12z or 12.00 WIB on January 15 2013 seen in Figure 2. The results of the 12z Rainfall Model from WRF (Weather Research and Forecasting) illustrate the absence of rainfall patterns in the city part of Semarang. However [9]

![Figure 3](image.png)

**Figure 3.** The relationship between the duration of rain with the intensity of rain

Figure 3. is the value of rainfall intensity that is processed into a graph of the relationship between the duration of rain in minutes with the intensity of rain in the return period of 2 years, 5 years, 10 years and 25 years. The rainfall intensity value obtained will then be used to determine the peak discharge value [12]

![Figure 4](image.png)

**Figure 4.** The relationship between C and the peak discharge of the 2-year return period

Figure 4 shows the change in peak discharge with respect to the C coefficient in the 2-year return period. The peak discharge generated when the coefficient is 0.2 is 32.96 m³/s and when the flow coefficient C reaches a maximum value of 0.75 the peak discharge that occurs is 116.1 m³/s.

![Figure 5](image.png)

**Figure 5.** The relationship between C and the peak discharge of the return period of 5 years
Figure 5. shows the change in the peak discharge value to the flow coefficient C in the return period of 5 years. Obtained the results of the calculation of peak discharge when the minimum C flow coefficient is 0.25 of 52.76 m$^3$/s and the peak discharge value when the maximum C flow coefficient is 0.8 is 168.84 m$^3$/s.

Figure 6. The relationship between C and the peak discharge of the 10-year return period

Figure 6. shows the change in the C flow coefficient with respect to time in the 10 year return period. Obtained the results of the calculation of peak flow when the minimum C flow coefficient is 0.25 of 64.16 m$^3$/s and the peak discharge value when the maximum C flow coefficient is 0.8 is 205.33 m$^3$/s.

Figure 7. Peak discharge for a 25-year return period

Figure 7 shows the change in the C flow coefficient with respect to time in the return period of 25 years. Obtained the calculation of peak discharge when the minimum C flow coefficient is 0.25 of 81.25 m$^3$/s and the peak discharge value when the maximum C flow coefficient is 0.8 is 260.01 m$^3$/s.

4. Conclusion
From the results and discussion of research on the Semarang City flood distribution prediction model, it can be concluded that the flood distribution occurs in the return period of 2 years and the return period of 5 years and 10 years and in the return period of 25 years. Obtained the peak discharge generated when the coefficient is worth 0.2 of 32.96 m$^3$/s and when the flow coefficient C reaches a maximum value of 0.75 the peak discharge that occurs is 116.1 m$^3$/s. Until the 25-year period shows a change in the flow coefficient C with the increase in peak discharge and also the effect of the C flow coefficient that continues to increase.
Reference

[1]  Gernowo R, Adi K, and Yulianto T 2017 Journal of Advanced Science Letters 23 6593–6597
[2]  Gernowo R, Adi K, Yulianto T, Seniyatis S and Yatunnisa A A 2018 IOP Conf. Series: Journal of Physics: Conf. Series 1025 (2018) 012023
[3]  Vahada A D, Saputra A H, Waseso M P G, Yushar R F and Hariado 2015 Journal of Meteorology Climatology and Geophysics 2(2) 1-9
[4]  Ellord G P and Knapp D I 1992 Weather and Forecasting 7 150– 165
[5]  Jaeger E B and Sprenger M 2007 Geophys. Rees. 112 D20106
[6]  NCAR 2014 User’s Guide For The Advanced Research WRF (ARW) Modeling System Version”, 3.6, (http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3/contents.htm)
[7]  NOAA Climate Data OnLine (https://www.ncdc.noaa.gov/cdo-web/)
[8]  Kogan Y L 1990 Journal of American Meteorological Society online (https://journals.ametsoc.org/doi/abs/10.1175/15200469(1991)048%3C1160:TSOACC%3E2.0.CO;2)
[9]  Arini E Y, Hidayat R and Faqih A 2015 Procedia Environmental Science 24 70-86
[10] Wisdom D and Suyatim 2014 Journal of Meteorology Climatology and Geophysics 2(3)
[11] Kain J S 2002 Journal of American Meteorological Society online (https://journals.ametsoc.org/doi/abs/10.1175/15200450(2004)043%3C0170:TKCPAU%3E2.0.CO;2)
[12] Keller J L 1981 J. appl. meteor. 20 686-692
[13] Sebastian S, Lugal L 2008 Journal of Civil Engineering Dynamics 8 162-169
[14] Coyle R G 1999 System Dynamics Modeling: A Practical Approach (London: Chapman and Hall)
[15] Forrester J W 1961 Industrial Dynamics (Cambridge: MIT Press)