# CHARACTERIZATION AND DISAGGREGATION OF DAILY RAINFALL DATA OF ONITSHA, ANAMBRA STATE, NIGERIA

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## ABSTRACT

Characterization and disaggregation of rainfall data is very important for locations where the existing rainfall data is scanty. This study characterizes and disaggregates the rainfall data of Onitsha, Anambra state, Nigeria, using simple mathematical and statistical models; especially the WMO guideline. The disaggregation process was carried out over a time series below 6hours for as small as 30 minutes to 10 seconds. Analysis of the rainfall characteristics of Onitsha showed a maximum intensity of 146.5mm/day occurring in March. Highest probability of dryness of 0.98 was observed in January and December. Maximum mean daily rainfall of 14.81mm and 14.51mm occurred in September and July respectively. Disaggregated results obtained with WMO guideline was compared with that of USDA SCS Generalized Accumulated rainfall curves. Both the curves derived from the WMO model and three USDA SCS Generalized Accumulated rainfall curves (A, B and C) increased together in a positive correlation but the WMO model's curve came closest to the curve B of the USDA, SCS model. This implies that the maximum intensity is usually reached in the middle of the storm duration in the tool.

## 1. INTRODUCTION

Hydrological processes are usually studied in different time scales. The problem is often how to generate consistent time series both in higher-level time scale and lower-level, time scale. An approach to solve this problem is to model the process in the lower-level time scale only, and then aggregate to derive the process in the higher-level time scale. In some cases, the higher-level process may be the output of a specialised model or known from measurements (e.g., daily rainfall measurements); in such cases the aggregation approach cannot work, but rather disaggregation is needed. This kind of problem is commonly tackled by disaggregation models. Several such models have been developed since the 1970s and utilised in numerous hydrological applications, including, among others, simulation of reservoir systems, either for design or operation purposes, storm and flood simulations, and even enhancement of hydrological data records. Since many scenarios occur at a coarse time scale, there is a need to transform them into a finer scale. However, according to Koutsoyiannis et al. ( 2003), disaggregation is not identical to downscaling, as the latter aims at producing finer scale time series with the required statistics but that do not necessarily add up to any given coarse scale totals. The guideline proposed by Michel and Ojha (2003) for the break-down and distribution of 6-hour rainfall over a 6-hour period is a very remarkable document in the research.

Available rainfall records for Onitsha are limited to daily time steps. Though rainfall data at shorter time steps are important for various purposes like modelling of erosion processes and flood hydrographs, they are hardly available in Nigeria. Hence, the objectives of this study are to characterize the rainfall data of Onitsha, disaggregate the rainfall data into fine-time scale and compare the obtained disaggregated results with the USDA SCS generalized accumulated rainfall curves results.

## 2. METHODOLOGY

### 2.1 Stochastic Rainfall Disaggregation: Review of Earlier Work

Stochastic disaggregation of rainfall is based on stochastic point processes. A simple stochastic point process of rainfall can be conceptualised by storms arriving in a Poisson process, and each storm is associated with a random and single rain cell of rectangular pulse with independent intensity and duration.

The rain cells can overlap, and the total rainfall intensity at any instance can be given by the sum of the intensities of all active rain cells at that instance. One of the shortcomings of this type of conceptual model is that they are not capable of accounting for the temporal statistics of rainfall at different aggregation levels (Rodriguez-Iturbe et al., 1987). Cluster based models such as Neyman-Scott and Bartlett-Lewis were introduced by Rodriguez-Iturbe et al., (1987 and 1988) as measures to overcome the shortcomings of the point processes. These cluster based rainfall models are actually based on the Poisson process with some adjustments. In the cluster based models, each storm produces a cluster of rain cells instead of one as in the simple Poisson point process, with each cell having random duration and intensity. From a statistical point of view both randomised and nonrandomised versions of the models are parametric analyses. Normally, these parameters are estimated by the method of moments.

Some of the remarkable works on stochastic rainfall disaggregation include the works by Cowpertwait et al. (1996) on disaggregation of hourly rainfall into smaller time intervals by allocating pulses of a specified small depth each, at the different intervals and Connolly et al. (1998) disaggregation of daily rainfall into a number of events following a Poisson process. A more systematic model, based on the Bartlett-Lewis rectangular pulse process, was studied by Koutsoyiannis et al., (2001). The above-mentioned models are generally based on classical probability and stochastic processes theory. In the last years there have been studied disaggregation techniques with different scientific bases. Thus, the development of multifractal simulation techniques has provided a potentially powerful tool for the exploration of problems such as disaggregation.

An application of this approach to the disaggregation problem was proposed by Olsson and Berndtsson (1997). The use of a self-similar micro canonical cascade enables the reproduction of the exact total daily rainfall, but it does not allow for the reproduction of the observed hourly autocorrelations. Bounded micro canonical cascades (Marshak et al., 1994) do however provide a tool, which could be used for disaggregation. Such approaches are promising, as illustrated by the successful reproduction of rainfall statistics with canonical bounded cascades (Menabde et al., 1997), but require more analysis, particularly in their ability to reproduce the dry period structure at different scales. A different approach has been followed by Burian et al., (2000) who used artificial neural networks to disaggregate hourly rainfall data into shorter time intervals. Yet another approach was followed by Sivakumar et al. (2001) who formed a simple chaotic model to disaggregate rainfall of five resolutions using techniques from the chaos literature. It must be mentioned however that the latter techniques that are not based on probability and stochastic processes may not be appropriate for large length simulations, as they do not perform well in extrapolation. For example they may result in poor description of extremes, whose study needs large length simulations.

A successful rainfall generation model capable of reproducing the particular fine scale structure of rainfall can be used as the lower-level model. This can then be combined with an appropriate procedure for adjusting the lower-level amounts so as to obtain the required higher-level totals. Such an implementation was done by Koutsoyiannis et al., (2001) and resulted in a computer program named Hyetos that can be easily applied at any location provided that a minimal amount of data is available that can support parameter estimation. The higher- and lower-level time scales in this implementation are respectively daily and hourly which are the most suitable for typical hydrological applications.

### 2.2 The Study Area

Onitsha is located in the south-eastern part of Nigeria. The area experiences highest daily rainfall in the months of July through September. There are two seasons in Onitsha similar to every other part in Nigeria, the wet season (April-October) and dry season (November-March).The dry season starts with Harmattan - a dry chilly spell with a dusty atmosphere brought about by the NE winds blowing from the Arabian Peninsula across the Desert. During the rainy season, a marked interruption in the rains occurs during August, resulting in a short dry season often referred to as the “August break”, though for years now this has not been consistent in August due to climate change. In the area, humidity and temperature are relatively high year-round. Though, humidity is lower in December and January during the Harmattan or dry season when cool dry winds blow off the desert (Okonkwo and Mbajiorgu, 2010).

## 2.3 Disaggregating Daily Rainfall into Individual Depths

The relationship between the small rainfall amount and the daily total amount is given as follows:

$$\sum_{i=1}^{Nc} y_{ci} = Zc \qquad \text{.......... (1)}$$

Where Nc = Number of Yci amounts of rainfall, Zc = daily total amount of rainfall, Yci = small rainfall amounts.

Transformation of the daily rainfall amount was done using the transformation model proposed by Hershenhorn and Woolhiser (1987). This transformation was necessary to convert the observed rainfall data to a value that will be compatible with a typical disaggregation model. The transformation is given as follows:

$$F\,(Zc) = 1\text{-}\exp\left[-\frac{\cancel{Z}}{\alpha}\right]^{\gamma} \qquad \text{.......... (2)}$$

where $\alpha$ = 7.617, $\gamma$ =0.7364, $\cancel{Z}$ = daily total amount of rainfall and F (Zc) = transformed daily total amount of rainfall

Usually, if there is scanty information about the actual starting time of a rainfall event, duration and interval, the local starting time is assumed. In the case of Onitsha meteorological station, there is no record of starting time, hence the need to assume them. This assumed local starting time also has to be transformed especially if the results will be applied to a disaggregation model. The transformation is done using the following relationship equation:

$$Tc = \frac{Uci}{24} \qquad \text{.......... (3)}$$

where Uci = observed starting time, Tc = transformed starting time

The above result is a general approach to the generation of a typical raw data for observed daily rainfall. It does not specify for an exact environmental purpose. But for agricultural purposes and watershed management in agriculture the time of concentration is often 6-hours (Michel and Ojha, 2003).

## 2.4 World Meteorological Organization (WMO) Guideline for Breaking Down 6 Hours Rainfall Data

The WMO guideline is a simple linear distribution and conformed to the simple linear regression model given by;

$$Y = \alpha + \beta x + \varepsilon \qquad \text{.......... (4)}$$

Where Y = percentage of rain, X = duration of rain, $\varepsilon$ = superimposed error component, $\alpha$ and $\beta$ = regression parameters.

But $$\alpha = \frac{\sum yi}{n} - \frac{\beta \sum xi}{n} = \overline{Y} - \beta\overline{X} \qquad \text{.......... (5)}$$

where n = number of observed data

$$\beta = \frac{\sum xiyi - \sum xi \sum yi}{n\sum x_i^2 - \left(\sum xi\right)^2} \quad \text{.......................................................} (6)$$

where Ȳ= mean percentage of rain, $\overline{X}$ = mean duration of rain, Yi= ith percentage of rain and Xi= duration of ith rain. Table 1 shows the estimation of the WMO model parameters.

Table 1: Estimation of the WMO model parameters

| S/N | X | Y | $X^2$ | XY | ε |
|---|---|---|---|---|---|
| 1 | 0 | 0.0 | 0 | 0 | 3.3 |
| 2 | 0.5 | 2.0 | 0.25 | 1.0 | -4.4 |
| 3 | 1.0 | 8.0 | 1.00 | 8.0 | -8.1 |
| 4 | 1.5 | 15.0 | 2.25 | 22.5 | -10.8 |
| 5 | 2.0 | 22.0 | 4.00 | 44.0 | -13.5 |
| 6 | 2.5 | 60.0 | 6.25 | 150.0 | 14.8 |
| 7 | 3.0 | 70.0 | 9.00 | 210.0 | 15.1 |
| 8 | 3.5 | 78.0 | 12.25 | 273.0 | 13.4 |
| 9 | 4.0 | 84.0 | 16.00 | 336.0 | 9.7 |
| 10 | 4.5 | 88.0 | 20.25 | 396.0 | 4.0 |
| 11 | 5.0 | 92.0 | 25.00 | 460.0 | -17.0 |
| 12 | 5.5 | 96.0 | 30.25 | 528.0 | -7.4 |
| 13 | 6.0 | 100.0 | 36.00 | 600.0 | -13.1 |
| ∑ | 39.0 | 715.0 | 162.5 | 3028.5 | -13.8 |

The error in given by:

ΣI = Yi - α - βxi ........................................................... (7)

Using the above equations and parameter values, the relationship is developed as follows:

Yi =- 3.3 + 19.4 Xi + ΣI .................................................. (8)

The extension is between 0.00 and 0.50 on X- axis and the error is determined by interpolation.

$$\frac{\sum_f - \nabla \sum_i}{\sum_f - \sum_x} = \frac{(Y_i - \sum_i)F - (Y_i - \sum_i)i}{(Y_i - \sum_i)_F - (Yi - \sum i)x} \quad \text{....................................} (9)$$

where Σx= the unknown error.

### 2.4 Disaggregated and Time Distributed Rainfall Data

According to Hershenhorn and Woolhiser (1987) the joint distribution function of the number of storm events and the transformed daily amount provided resolutions for one storm event and as much as six storm events on a rain day. However it was observed that there can only be a maximum of four storm events and a minimum of one storm event on a typical rain day. Hence both the assumed number of storm events and the individual storm depths were made to satisfy the conditions of aggregation and observable number of events. Applying the WMO model with the observed duration of individual rainfall depths, the time distributed rainfall depths were gotten and compared with the assumed individual storm depths.

Both the starting time and duration of individual storms were assumed, however the time distributed rainfall depth was arrived at by multiplying the percentage ratio of rainfall amount corresponding to the duration of individual storm events as suggested by the WMO guideline, with the converted 6-hour rainfall of a given daily rainfall total. This will generate results of time distributed and disaggregated rainfall data which sums up as closely as possible to the coarse or 24-hour rainfall total.

## 2. RESULTS

### 3.1 Daily Rainfall Characterization Results

The daily rainfall characteristics of Onitsha are summarised in Table 2 below. It was obtained by statistically analysing the daily rainfall record from the month of January to December for 30 years.

Table 2: Daily Rainfall Characteristics of Onitsha

| Months | Mean Rainfall intensity | STD | Var. | Prob (dry) | C.V. | Mean rain days | Max. intensity | No of wet/dry spell days |
|---|---|---|---|---|---|---|---|---|
| January | 10.35 | 14.27 | 203.71 | 0.98 | 0.73 | 0.84 | 59.2 | 1/30 |
| February | 11.46 | 12.81 | 164.06 | 0.97 | 0.89 | 2.11 | 46.0 | 1/27 |
| March | 11.88 | 18.42 | 339.38 | 0.90 | 0.64 | 4.71 | 146.5 | 1/21 |
| April | 14.03 | 15.68 | 245.93 | 0.87 | 0.89 | 9.23 | 102.8 | 2/14 |
| May | 15.71 | 18.17 | 330.01 | 0.56 | 0.86 | 14.16 | 98.3 | 2/5 |
| June | 13.84 | 17.48 | 305.54 | 0.37 | 0.79 | 18.00 | 97.1 | 3/2 |
| July | 14.51 | 19.42 | 376.95 | 0.05 | 0.75 | 19.58 | 172.4 | 7/1 |
| August | 11.69 | 17.64 | 311.11 | 0.07 | 0.66 | 21.13 | 137.0 | 6/1 |
| September | 14.81 | 19.14 | 366.38 | 0.20 | 0.77 | 20.53 | 94.5 | 3/2 |
| October | 13.19 | 17.21 | 296.38 | 0.68 | 0.77 | 19.19 | 124.8 | 2/5 |
| November | 6.98 | 9.36 | 87.67 | 0.89 | 0.75 | 3.83 | 55.6 | 1/15 |
| December | 7.18 | 7.90 | 62.45 | 0.98 | 0.91 | 0.97 | 28.1 | 1/30 |

**Observed and Transformed Rainfall Data:**
Table 3 below describes the observed and transformed rainfall data. It shows the transformed results computed as explained previously.

Table 3: Observed and Transformed Rainfall Data

| S/N | No. of Rainfall events | Observed coarse rainfall depth (min) | Transformed coarse rainfall depth (mm) | Observed fine-scale rainfall depth (mm) | Transformed fine-scales rainfall depth (mm) | Observed starting time (hr) | Transformed start time (hr) | Observed rainfall duration (Min) | Transformed rainfall duration (Min) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 10.35 | 0.7144 | 5.10 | 0.5250 | 00.30 | 0.0125 | 3.50 | 1.253 |
| | | | | 5.25 | 0.5325 | 01.30 | 0.0542 | 4.50 | 1.504 |
| 2 | 3 | 11.46 | 0.7410 | 3.05 | 0.3993 | 02.30 | 0.0958 | 2.50 | 0.916 |
| | | | | 3.95 | 0.4602 | 03.30 | 0.1375 | 1.50 | 0.405 |
| | | | | 4.46 | 0.4905 | 04.30 | 0.1792 | 5.00 | 1.609 |
| 3 | 2 | 11.88 | 0.7502 | 5.90 | 0.5633 | 05.30 | 0.2208 | 3.00 | 1.099 |
| | | | | 5.98 | 0.5669 | 06.30 | 0.2625 | 5.50 | 1.705 |
| 4 | 3 | 14.03 | 0.7915 | 4.50 | 0.4927 | 07.30 | 0.3042 | 3.50 | 1.253 |
| | | | | 4.95 | 0.5172 | 08.30 | 0.3458 | 3.50 | 1.253 |
| | | | | 4.58 | 0.4972 | 09.30 | 0.3875 | 1.00 | 0.000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 4 | 15.71 | 0.8181 | 3.90 | 0.4571 | 10.30 | 0.4290 | 3.50 | 1.253 |
| | | | | 4.10 | 0.4694 | 11.30 | 0.4708 | 2.50 | 0.916 |
| | | | | 3.50 | 0.4311 | 12.30 | 0.5125 | 1.00 | 0.000 |
| | | | | 4.21 | 0.4760 | 13.30 | 0.5542 | 1.50 | 0.405 |
| 6 | 2 | 13.84 | 0.7882 | 6.00 | 0.5678 | 14.30 | 0.5958 | 3.50 | 1.253 |
| | | | | 7.84 | 0.6399 | 15.30 | 0.6375 | 4.50 | 1.504 |
| 7 | 4 | 14.51 | 0.7996 | 3.65 | 0.4411 | 16.30 | 0.6792 | 2.00 | 0.693 |
| | | | | 3.00 | 0.3956 | 17.30 | 0.7208 | 2.00 | 0.693 |
| | | | | 4.85 | 0.5119 | 18.30 | 0.7625 | 2.50 | 0.916 |
| | | | | 3.01 | 0.3963 | 19.30 | 0.8042 | 2.50 | 0.916 |
| 8 | 3 | 11.69 | 0.7461 | 4.00 | 0.4633 | 20.30 | 0.8458 | 2.00 | 0.693 |
| | | | | 3.85 | 0.4540 | 21.30 | 0.8875 | 2.50 | 0.916 |
| | | | | 3.84 | 0.4533 | 22.30 | 0.9292 | 3.50 | 1.253 |
| 9 | 4 | 14.81 | 0.8044 | 3.70 | 0.4443 | 23.30 | 0.9708 | 1.50 | 0.405 |
| | | | | 3.00 | 0.3956 | 00.30 | 0.0125 | 2.00 | 0.693 |
| | | | | 4.95 | 0.5172 | 01.30 | 0.0542 | 2.50 | 0.916 |
| | | | | 3.16 | 0.4074 | 02.30 | 0.0958 | 3.00 | 1.099 |
| 10 | 3 | 13.19 | 0.7765 | 4.30 | 0.4813 | 03.30 | 0.1375 | 2.00 | 0.693 |
| | | | | 4.95 | 0.5172 | 04.30 | 0.1792 | 3.50 | 1.253 |
| | | | | 3.94 | 0.4596 | 05.30 | 0.2208 | 2.50 | 0.916 |
| 11 | 3 | 6.98 | 0.6085 | 2.30 | 0.3390 | 06.30 | 0.2625 | 3.00 | 1.099 |
| | | | | 3.55 | 0.4345 | 07.30 | 0.3042 | 3.50 | 1.253 |
| | | | | 1.13 | 0.2176 | 08.30 | 0.3458 | 1.50 | 0.405 |
| 12 | 2 | 7.18 | 0.6161 | 3.90 | 0.4571 | 09.30 | 0.3875 | 4.00 | 1.386 |
| | | | | 3.28 | 0.4159 | 10.30 | 0.4292 | 3.50 | 1.253 |

**Statistical Extension of the WMO Guideline:**

The WMO guideline provided percentage rainfall resolutions for period of rainfall at a 0.5 interval. But the resolution is required in periods below 0.5hours. Table 4 shows the statistical extension of the WMO Model

Table 4: Statistical Extension of the WMO Model

| S/N | Time (hr) or x | % of rain or y | (y-ε) | Error (ε) |
|---|---|---|---|---|
| 1 | 0.000 | 0.000 | -3.300 | 3.300 |
| 2 | 0.001 | 0.004 | -3.280 | 3.284 |
| 3 | 0.005 | 0.021 | -3.200 | 3.221 |
| 4 | 0.010 | 0.039 | -3.110 | 3.149 |
| 5 | 0.015 | 0.060 | -3.010 | 3.070 |
| 6 | 0.020 | 0.080 | -2.910 | 2.990 |
| 7 | 0.050 | 0.200 | -2.330 | 2.530 |
| 8 | 0.100 | 0.400 | -1.360 | 1.760 |
| 9 | 0.150 | 0.600 | -0.390 | 0.990 |
| 10 | 0.200 | 0.800 | 0.580 | 0.220 |
| 11 | 0.250 | 1.000 | 1.550 | -0.550 |
| 12 | 0.300 | 1.200 | 2.520 | -1.320 |
| 13 | 0.350 | 1.400 | 3.490 | -2.090 |
| 14 | 0.400 | 1.600 | 4.460 | -2.860 |
| 15 | 0.450 | 1.800 | 5.430 | -3.630 |
| 16 | 0.500 | 2.000 | 6.400 | -4.400 |

| | | | | |
|---|---|---|---|---|
| 17 | 1.000 | 8.000 | 16.100 | -8.100 |
| 18 | 1.500 | 15.000 | 25.800 | -10.800 |
| 19 | 2.000 | 22.000 | 35.500 | -13.500 |
| 20 | 2.500 | 60.000 | 45.200 | 14.800 |
| 21 | 3.000 | 70.000 | 54.900 | 15.100 |
| 22 | 3.500 | 78.000 | 64.600 | 13.400 |
| 23 | 4.000 | 84.000 | 74.300 | 9.700 |
| 24 | 4.500 | 88.000 | 84.000 | 4.000 |
| 25 | 5.000 | 92.000 | 109.000 | -17.000 |
| 26 | 5.500 | 96.000 | 103.400 | -7.400 |
| 27 | 6.000 | 100.000 | 113.100 | -13.100 |

**Disaggregated and Time Distributed Data Results:**
Table 5 below gives a general overview of the disaggregated rainfall data over different time intervals. For each event of a given rainfall duration, there is a corresponding disaggregated result to be expected.

Table 5: Disaggregated and Time Distributed Data

| S/N | No of events | Coarse Rainfall Depth | Total daily rainfall | Disaggregated Rainfall depth | Duration of rainfall (hr) | Local Starting time | Time distributed and disaggregated rainfall |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 6.210 | 10.35 | Yc1 =5.10 | 3.50 | 00.30 | 4.844 |
| | | | | Yc2 = 5.25 | 4.50 | 01.30 | 5.465 |
| 2 | 3 | 6.878 | 11.46 | Yc3 = 3.05 | 2.50 | 02.30 | 4.127 |
| | | | | Yc4 = 3.95 | 1.50 | 03.30 | 1.032 |
| | | | | Yc1 =4.46 | 5.00 | 0.4.30 | 6.328 |
| 3 | 2 | 7.128 | 11.88 | Yc2 =5.90 | 3.00 | 05.30 | 4.990 |
| | | | | Yc3 = 5.98 | 5.50 | 06.30 | 6.843 |
| 4 | 3 | 8.418 | 14.03 | Yc4 = 4.50 | 3.50 | 07.30 | 6.566 |
| | | | | Yc1 = 4.95 | 3.50 | 08.30 | 6.566 |
| | | | | Yc2 =4.58 | 1.00 | 09.30 | 0.168 |
| 5 | 4 | 9.426 | 15.71 | Yc3 = 3.90 | 3.50 | 10.30 | 7.352 |
| | | | | Yc4 =4.10 | 2.50 | 11.30 | 5.656 |
| | | | | Yc1 = 3.50 | 1.00 | 12.30 | 0.784 |
| | | | | Yc2 = 4.21 | 1.50 | 13.30 | 1.414 |
| 6 | 2 | 8.304 | | Yc3 = 6.00 | 3.50 | 14.30 | 6.477 |
| | | | | Yc4 = 7.84 | 4.50 | 15.30 | 7.308 |
| 7 | 4 | 8.706 | | Yc1 = 3.65 | 2.00 | 16.30 | 1.915 |
| | | | | Yc2 =3.00 | 2.00 | 17.30 | 1.915 |
| | | | | Yc3 = 4.85 | 2.50 | 18.30 | 5.224 |
| | | | | Yc4 = 3.07 | 2.50 | 19.30 | 5.224 |
| 8 | 3 | 7.014 | 11.69 | Yc1 = 4.00 | 2.00 | 2.30 | 1.543 |
| | | | | Yc2 =3.85 | 2.50 | 21.30 | 4.208 |
| | | | | Yc3 =3.84 | 3.50 | 22.30 | 5.471 |
| 9 | 4 | 8.886 | 14.81 | Yc4 = 3.70 | 1.50 | 23.30 | 1.333 |
| | | | | Yc1 = 3.00 | 2.00 | 00.30 | 1.955 |
| | | | | Yc2 = 4.95 | 2.50 | 01.30 | 5.332 |
| | | | | Yc3 = 3.16 | 3.00 | 02.30 | 6.220 |
| 10 | 3 | 7.914 | 13.19 | Yc1 =4.30 | 2.00 | 03.30 | 1.741 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Yc2= 4.95 | 3.50 | 04.30 | 6.173 |
| | | | | Yc3 =3.94 | 2.50 | 05.30 | 4.748 |
| 11 | 3 | 4.188 | 6.98 | Yc1 =2.30 | 3.00 | 06.30 | 2.932 |
| | | | | Yc2 =3.55 | 3.50 | 07.30 | 3.267 |
| | | | | Yc3 =1.13 | 1.50 | 08.30 | 0.628 |
| 12 | 3 | 4.308 | 7.18 | Yc1 =3.90 | 4.00 | 09.30 | 3.619 |
| | | | | Yc2 =3.28 | 3.50 | 10.30 | 3.360 |

**30 Minutes Rainfall Data of Onitsha:**
Table 6 below shows the results of 30 minutes rainfall expected using the WMO guideline, for the rainfall record of Onitsha.

Table 6: Thirty Minutes Rainfall Data of Onitsha

| S/N | No of rainfall events | Total daily rainfall | 24-hr. (mm) disaggregated rainfall | Local starting time(hr) | 30-mins disaggregated rainfall result (mm) | 6hrs disaggregated rainfall results |
|---|---|---|---|---|---|---|
| 1 | 2 | 10.35 | 5.10 | 00.30 | 0.0612 | 3.06 |
| | | | 5.25 | 01.30 | 0.0630 | 3.15 |
| 2 | 3 | 11.46 | 3.05 | 02.30 | 0.0366 | 1.83 |
| | | | 3.95 | 03.30 | 0.0474 | 2.37 |
| | | | 4.46 | 04.30 | 0.0536 | 2.68 |
| 3 | 2 | 11.88 | 5.90 | 05.30 | 0.0708 | 3.54 |
| | | | 5.98 | 06.30 | 0.0718 | 3.59 |
| 4 | 3 | 14.03 | 4.50 | 07.30 | 0.0540 | 2.70 |
| | | | 4.95 | 08.30 | 0.0594 | 2.97 |
| | | | 4.58 | 09.30 | 0.0550 | 2.75 |
| 5 | 4 | 15.71 | 3.90 | 10.30 | 0.0468 | 2.34 |
| | | | 4.10 | 11.30 | 0.0492 | 2.46 |
| | | | 3.50 | 12.30 | 0.0420 | 2.10 |
| | | | 4.21 | 13.30 | 0.0506 | 2.53 |
| 6 | 2 | 13.84 | 6.00 | 14.30 | 0.0720 | 3.60 |
| | | | 7.84 | 15.30 | 0.0940 | 4.70 |
| 7 | 4 | 14.51 | 3.65 | 16.30 | 0.0438 | 2.19 |
| | | | 3.00 | 17.30 | 0.0360 | 1.80 |
| | | | 4.85 | 18.30 | 0.0582 | 2.91 |
| | | | 3.01 | 19.30 | 0.0362 | 1.81 |
| 8 | 3 | 11.69 | 4.00 | 20.30 | 0.0480 | 2.40 |
| | | | 3.85 | 21.30 | 0.0462 | 2.31 |
| | | | 3.84 | 22.30 | 0.0460 | 2.30 |
| 9 | 4 | 14.81 | 3.70 | 23.30 | 0.0444 | 2.22 |
| | | | 3.00 | 00.30 | 0.0360 | 1.80 |
| | | | 4.95 | 01.30 | 0.0594 | 2.97 |
| | | | 3.16 | 02.30 | 0.0380 | 1.90 |
| 10 | 3 | 13.19 | 4.30 | 03.30 | 0.0516 | 2.58 |
| | | | 4.95 | 04.30 | 0.0594 | 2.97 |
| | | | 3.94 | 05.30 | 0.0472 | 2.36 |
| 11 | 2 | 06.98 | 2.30 | 06.30 | 0.0276 | 1.38 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 3.55 | 07.30 | 0.0426 | 2.13 |
| | | | 1.13 | 08.30 | 0.0136 | 0.68 |
| 12 | 2 | 07.18 | 3.90 | 09.30 | 0.0468 | 2.34 |
| | | | 3.28 | 10.30 | 0.0394 | 1.97 |

**Fine-time Scale Rainfall Data Results:**
Other smaller resolutions for the disaggregated rainfall results are presented in Table 7 below. This is done by applying the WMO guideline.

Table 7: Fine Time Scale Rainfall Data

| S/N | 6hrs disaggregated rainfall depth (mm) | 15 min disaggregated rainfall depth (mm) | 9 min disaggregated rainfall depth (mm) | 60 sec disaggregated rainfall depth (mm) (x 10-4) | 30 sec disaggregated rainfall depth (mm) (x 10-4) | 10 sec disaggregated rainfall depth (mm) (x 10-4) |
|---|---|---|---|---|---|---|
| 1 | 3.06 | 0.0306 | 0.0184 | 20.196 | 9.18 | 3.366 |
| 2 | 3.15 | 0.0315 | 0.0189 | 20.790 | 9.45 | 3.465 |
| 3 | 1.83 | 0.0183 | 0.0110 | 12.078 | 5.49 | 2.013 |
| 4 | 2.37 | 0.0237 | 0.0142 | 15.642 | 7.11 | 2.607 |
| 5 | 2.68 | 0.0268 | 0.0161 | 17.688 | 8.04 | 2.948 |
| 6 | 3.54 | 0.0354 | 0.0212 | 23.364 | 10.62 | 3.894 |
| 7 | 3.59 | 0.0359 | 0.0215 | 23.694 | 10.77 | 3.949 |
| 8 | 2.70 | 0.0270 | 0.0162 | 17.820 | 8.10 | 2.970 |
| 9 | 2.75 | 0.0275 | 0.0165 | 18.150 | 8.25 | 3.025 |
| 10 | 2.34 | 0.0234 | 0.0140 | 15.444 | 7.02 | 2.574 |
| 11 | 2.46 | 0.0246 | 0.0148 | 16.236 | 7.38 | 2.706 |
| 12 | 2.10 | 0.0210 | 0.0126 | 13.860 | 6.30 | 2.310 |
| 13 | 2.53 | 0.0253 | 0.0152 | 16.698 | 7.59 | 2.783 |
| 14 | 3.60 | 0.0360 | 0.0216 | 23.760 | 10.80 | 3.960 |
| 15 | 4.70 | 0.0470 | 0.0282 | 31.020 | 14.10 | 5.170 |
| 16 | 2.19 | 0.0219 | 0.0131 | 14.454 | 6.57 | 2.409 |
| 17 | 1.80 | 0.0180 | 0.0108 | 11.880 | 5.40 | 1.980 |
| 18 | 2.91 | 0.0291 | 0.0175 | 19.206 | 8.73 | 3.201 |
| 19 | 2.40 | 0.0240 | 0.0144 | 11.946 | 7.20 | 2.640 |
| 20 | 2.31 | 0.0231 | 0.0139 | 15.840 | 6.93 | 2.541 |
| 21 | 2.30 | 0.0230 | 0.0138 | 15.246 | 6.90 | 2.530 |
| 22 | 2.22 | 0.0222 | 0.0133 | 15.180 | 6.66 | 2.442 |
| 23 | 1.80 | 0.0180 | 0.0108 | 14.652 | 5.40 | 1.980 |
| 24 | 2.97 | 0.0297 | 0.0178 | 11.880 | 8.91 | 3.267 |
| 25 | 1.90 | 0.0190 | 0.0114 | 19.602 | 5.70 | 2.090 |
| 26 | 2.58 | 0.0258 | 0.0155 | 12.540 | 7.74 | 2.838 |
| 27 | 2.97 | 0.0297 | 0.0178 | 17.028 | 8.91 | 3.267 |

**Comparison of 2hr Disaggregated Rainfall with the USDA Generalized Accumulated Rainfall Curves**

The USDA SCS (1955) generalized accumulated rainfall curve gives the breakdown of percentages of rainfall that can be expected for a proportionate duration of storm. It comprises of three curves (Figure 1); curve A is for advanced type in which the highest intensity occurs in the early part of the storm, Curve B is for the highest intensity occurring in the middle of the storm, and curve C is for the highest intensity occurring late in the storm duration. Table 8 shows the comparison of the results generated from the disaggregation of Onitsha as compared to the results of curve A, curve B and curve C of the USDA SCS (1955) model

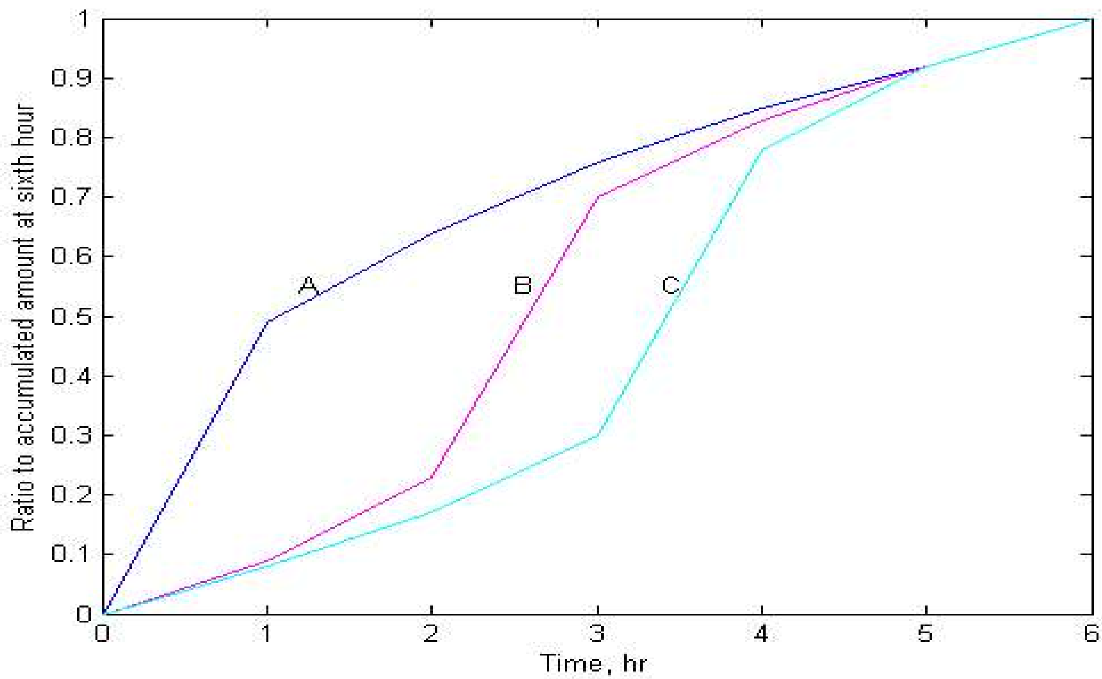


Fig 1: Generalized accumulated rainfall curves for A (advanced), B (intermediate), and C (retarded) types of storms. (USDA SCS, 1955)

Table 8: Comparison of Results

| S/N | Disaggregated Rainfall Result | Curve A result (mm) | Curve B result (mm) | Curve C result (mm) |
|---|---|---|---|---|
| 1 | 0.6732 | 1.9278 | 0.6732 | 0.5202 |
| 2 | 0.6930 | 1.9845 | 0.6930 | 0.5355 |
| 3 | 0.4026 | 1.1529 | 0.4026 | 0.3111 |
| 4 | 0.5214 | 1.4931 | 0.5214 | 0.4029 |
| 5 | 0.5896 | 1.6884 | 0.5896 | 0.4556 |
| 6 | 0.7788 | 2.2302 | 0.7788 | 0.6018 |
| 7 | 0.78998 | 2.2617 | 0.7898 | 0.6103 |
| 8 | 0.5940 | 1.7010 | 0.5940 | 0.4490 |
| 9 | 0.6534 | 1.8711 | 0.6534 | 0.5090 |
| 10 | 0.6050 | 1.7325 | 0.6050 | 0.4675 |
| 11 | 0.5148 | 1.4742 | 0.5148 | 0.3978 |
| 12 | 0.5412 | 1.5498 | 0.5412 | 0.4182 |

### 3.2 Daily Rainfall Data Characterization and Data Analysis

The average number of rain day varied from 0.84 days in the dry month to 21 days in the wet month. The wet period is greater than the dry period. The wet/dry spell length varied from 1/30 in the dry season to 7/1 in the rainy season. This indicated the occurrence of wet and dry spell days in groups which is caused by the persistence of synoptic scale weather system.

**Temporal Characteristics of Rainfall Variation**

The variability of the daily rainfall intensity was high in all months as depicted by larger coefficients of variation. The mean daily rainfall intensity varied from about 6mm in dry seasons to 15mm in the wet season. Overall, the daily rainfall intensity was highest in the middle of storm periods. The observed maximum intensity varied from 46mm to about 170mm, while the dry probability varied from 0.91 in dry seasons to 0.66 in wet seasons.

**Variation of Coarse and Disaggregated Data**

The coarse rainfall data is the 24-hours rainfall data while the fine or disaggregated rainfall data is the rainfall data below 6-hour. The individual depths were resolved so that they sum up to the coarse depth as close as possible. This is reflected in the positive correlation of the coarse and disaggregated data. Both increased and decreased together.

**Comparison with the Generalized Accumulated rainfall curves**

The disaggregated rainfall results of Onitsha was applied to the generalized accumulated curve at various durations below 6-hour. Comparing the result with the ratio of each curve (figure 2) showed a close correlation of the rainfall result of Onitsha with curve B, this implies that the maximum intensity is usually reached in the middle of the storm duration.

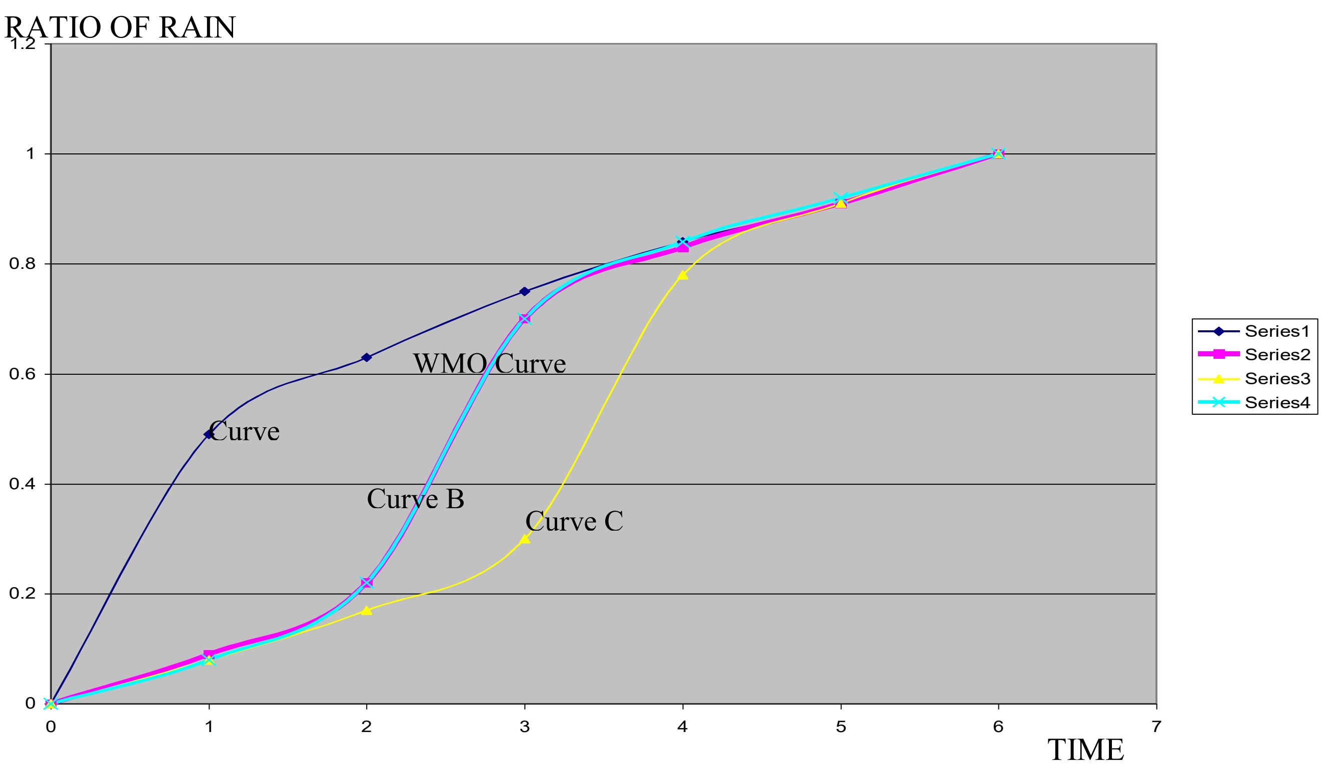


Figure 2: Comparison with the Generalized Accumulated rainfall curves (USDA 1955)

## 3. CONCLUSIONS

The simple regression model was a good fit for the WMO guideline. This model helped in the statistical extension of the guideline so as to obtain resolutions for smaller percentage of rainfall at smaller time intervals. However more complex statistical models and mathematical approach should provide more precise results for fine-scale rainfall resolutions. The rainfall characteristics of Onitsha can be summarized as predominantly rainy, having a total of seven wet months and five dry months i.e. April to November and November to March. The daily rainfall characteristics were similar to tropical climates. Most of the rainfall occurred in the morning and evening hours. Also comparing the result with the ratio of each curve of the generalized accumulated rainfall curves (USDA SCS 1955) showed a close correlation of the rainfall result of Onitsha with curve B. This implies that the maximum intensity is usually reached in the middle of the storm duration.

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