Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara

Seria ELECTRONICĂ şi TELECOMUNICAŢII
TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Tom 51(65), Fascicola 1, 2006

Analysis and modeling of rain characteristics

Sandra Rugină, Georgiana Sârbu-Doagă, Aurel Gontean, Marius Otesteanu[1]

Abstract – Realistic modeling of rain characteristics is important in several domains, such as meteorology, agriculture and transportation. Rain generators need to have reproducible characteristics, while being able to simulate variability existing in natural rains. In the present work, several characteristics of natural rains were analyzed, then several working parameters of a rain generator were proposed and simulated.

Keywords: rain generator, rain modeling, statistics

I INTRODUCTION

The main objective of this work is modeling rain generators with controlled and reproducible characteristics. This leads to the problem of characterizing rains, and to decide which characteristics of natural rains have to be measured and controlled by the rain generator.

To this end some relevant papers modeling rain characteristics are briefly reviewed and it is shown how the desired characteristics can be obtained for artificially generated rain.

II. DEFINITIONS OF DIFFERENT RAIN TYPES

According to the Romanian National Institute of Meteorology (INMH) [1], rainfall can be classified as follows:

a) Light rainfall = precipitation in the form of rare, isolated drops, which leave traces on surfaces, and that lasts for a period longer than 2 minutes. The noise produced by the falling of the drops is small. This type of rain doesn't abase visibility under 10km; nevertheless, a decrease in visibility can be observed when the light rain starts falling again after a temporary discontinuity of rainfall, or by the diminishing of a heavier previous rainfall; fog is created under these conditions, by evaporating water from wet surfaces.

b) Moderate rainfall = in the form of compact drops, that can be isolated easily and which wet the surface quickly. The noise produced by this type of rainfall on roofs, spouts, leaves can be very well distinguished. Horizontal visibility is reduced below 10km, but is usually more than 4km.

c) Heavy rainfall = type of precipitation that falls in the form of waves, individual drops are no longer observable and water gathers quickly on surfaces. The noise produced by this type of rainfall is similar to a loud rattle. Horizontal visibility is reduced to less than 4 km.

Rainfall classification by rain rates according to INMH [1] is summarized in Table 1.

Table 1.
Rainfall classification according to INMH [1]:

Type of Rainfall	**Rain Rate [liters/m^2]**
Moderate	5 during 3h
Heavy	15 during 3h
Very heavy	15 in less than 3 hours
Maximum rainfall: 25l/m^2/1h	

II. RAINFALL PARAMETERS

The most important parameter of the rain is the amount of rainfall. The amount of rainfall is measured using a rain gauge. The most common intervals of measuring rainfall are: per hour, per 30 minutes and per 3 hours. It is expressed as the depth of water that collects on a flat surface, and can be measured to the nearest 0.25 mm. It is sometimes expressed in liters per square meter (1 L/m² corresponding to 1 mm).

Closely related to the amount of rainfall is the rain rate, measuring the amount of the rainfall in a time unit. Usually the time unit is one hour or one minute. The rain rate depends on several parameters of the rain, like raindrop equivalent diameter, or raindrop concentration. Raindrop diameter is in relation with the falling speed, or velocity.

Raindrops generally have a diameter greater than 0.5 mm. Precipitation with raindrops of less than 0.5 mm in diameter is called drizzle and often severely restricts visibility, but usually does not produce significant accumulations of water.

III. RAIN MODELING

In the following, some methods of modeling rain are presented, as found in literature.

a) Velocity studies

[1] Facultatea de Electronică şi Telecomunicaţii, Departamentul Comunicaţii Bd. V. Pârvan Nr. 2, 403314 Timişoara, e-mail: sandra.rugina@etc.upt.ro; georgiana.sarbu@etc.up.ro; aurel.gontean@etc.upt.ro; marius.otesteanu@etc.upt.ro

The velocity-diameter relation has been modeled by the equations [2]:

$$v(D) = 3.78 \cdot D^{0.67} \quad (1)$$

where the velocity v is measured in [m/s] and the diameter D in [mm].

Some studies [3] use a different equation:

$$v(D) = 9.65 - 10.3 \cdot e^{-0.6 \cdot D} \quad (2)$$

b) Raindrop size distribution

The distribution of sizes in a rain usually contains a wide range of drop diameters. Small drops generally outnumber large drops, but as the intensity of the rainfall increases, the number of larger drops grows. The largest drops are found only in downpours with rainfall rates greater than 5 cm per hour. The size of raindrops can be classified as in table 2, according to [4].

Table 2.

The size of raindrop, [3]

Typical Particle Type	Typical Diameter (mm)
Cloud droplet	0.012
Large cloud droplet	0.1
Mist droplet	0.5
Drizzle Drop	1.2
Raindrop	3.0
Large Raindrop	6.0

Rain size distributions have been modeled by several authors. The most popular model remains the Marshall-Palmer model of the size distribution [5]:

$$n(D_d) = 8.0 \cdot 10^{-2} \cdot e^{-4.1 \cdot R^{-0.21} \cdot D_d} \quad (3)$$

R: rain intensity,

Dd: raindrop diameter,

n(Dd): the probability density function of the raindrop diameter.

According to probability theory, the mean drop diameter is [6]:

$$D_{mean} = \frac{1}{4.1 \cdot R^{-0.21}} \quad (4)$$

where D_{mean} is measured in mm and R in mm/h.

The log-normal distribution [7] is another widely used model:

$$y = f\left(\frac{x}{\mu}, \sigma\right) = \frac{1}{x \cdot \sigma \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{(\ln x - \mu)^2}{2 \cdot \sigma^2}} \quad (5)$$

For the log-normal distribution model, the geometric mean diameter is found to be [7]:

$$D_{dg} = 0.72 \cdot R^{0.23} \quad (6)$$

The above models lead to significantly different results. Also experimental data reported in the literature [8, 9, 10] show large differences. Such differences can be related to different environmental conditions (oceans, continent temperature, pressure etc.). However, all estimations lead to the conclusion that the mean diameter of the raindrop is increasing with the rain intensity. The variance of the diameter is of the same order of magnitude as the diameter itself. This is also in agreement with the theoretical models.

Note that the distribution measured with a modern disdrometer in experiments [2] is obtained at (real) variable rain intensity.

IV. RAIN SIMULATION

The objective is to obtain the volumetric contributions of raindrops with different diameters in relation with the total amount of the rain, assuming a constant rain rate. No study of this kind has been found in literature. All the studies found in literature focus on rainfall intensity, raindrop size distribution and velocity studies. In the hypothesis of creating an artificial rain generator, the volumetric contributions of raindrops with different diameters is a very important statistic for the user.

The rain generator under design has to be able to generate several types of rain. For each type of rain, it is important to control the raindrop size distributions expressed in volumetric contributions to the total volume of rain. The proposed rainfall parameters are presented in the table below:

Table 3

Proposed rainfall parameters

Nr	Type of rainfall	Volume of rainfall
IV	Very heavy	> 16 mm/h
III	Heavy	7.5 – 16 mm/h
II	Moderate	< 7.5 mm/h
I	Light	< 2.5 mm/h

The simulation of equation (1), resulting in Figure 1:

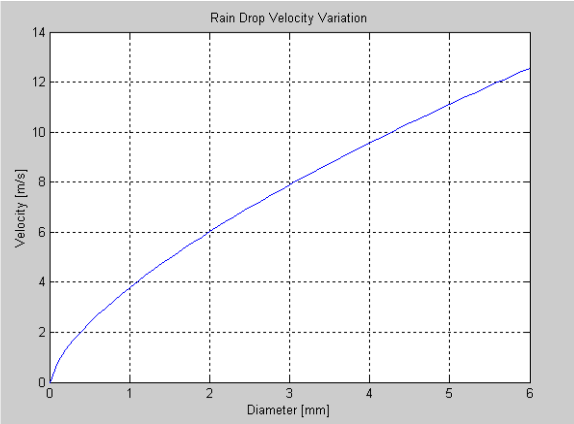

Figure 1. Rain Drop Velocity Variation.

The differences between the velocity equation given by (1) and (2) were studied.
The results of the simulation are given in Figure 2:

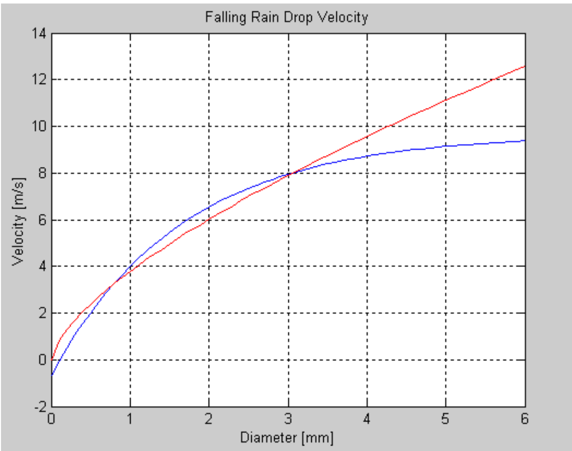

Figure 2. Comparison between the results obtained by using equation (1) - red and equation (2) - blue

In a further study, three types of rains with different intensities and mean diameters were simulated. For each type of rain, three percentages from the number of drops were defined. For each percentage and rain type, the diameter ranges were calculated, using the Palmer-Marshall distribution (3). The results are shown in table 4.

Table 4.
Diameters of different percentages of rain drops for given mean diameters

D_{mean}=1	D_{mean} =2	D_{mean} =3
40% (0.5-1.5mm)	40% (1-3mm)	40% (1.5-4.5mm)
60% (0.1-1.9mm)	60% (0.4-3.6mm)	60% (0.6-5.4mm)
80% (0.1-1.9mm)	80% (0.2-3.8mm)	80% (0.3-5.7mm)

The Palmer-Marshall distribution law better expresses the reality for big and medium raindrop diameters, which is why it offers not so accurate results for small and medium rain intensity. It tends to generate raindrops with smaller diameters than those that can be found by measurements in reality [11, 12]. This result is in part a consequence of the limitations of the measuring devices for small size drop diameters.

For given rain rates, the mean diameter values were determined with the Palmer Marshall distribution. The results, given in Table 5, show that the diameters are very small. On the other hand, for given diameters, very large rain rates resulted when calculated with equation (3).

Table. 5
Mean diameters for given rain rates

Rain Intensity	R=2.5mm/h	R=7.5mm/h	R=16mm/h
Mean Diameter	D_{mean} =0.3mm	D_{mean} =0.375	D_{mean} =0.44

Using a log-normal diameter distribution model, the volumetric contributions to the amount of the rain have been computed for raindrops with different diameters, assuming a constant rain rate. The results are shown in Figure 3.

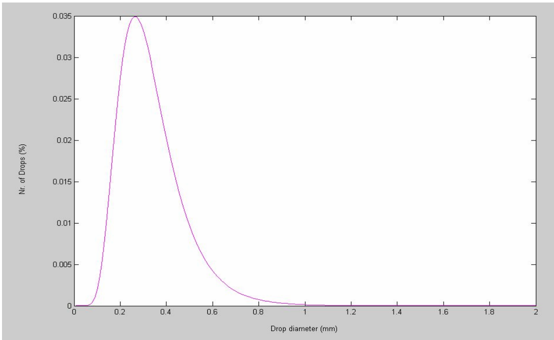

Figure 3. Total amount of the rain with the diameter distribution

The cumulative volume probability function, based on similar simulations is illustrated in figure 4.

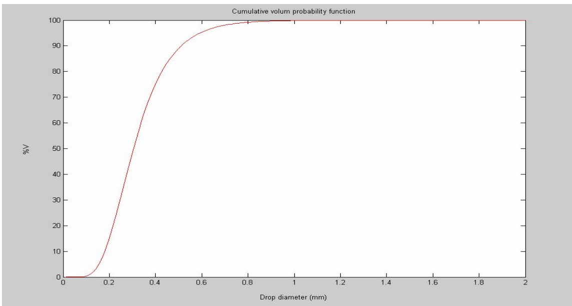

Figure 4. Cumulative volume probability function

Based on the same simulations, the contributions of several diameter ranges, covering 50%, 60% and 80% of the total amount of the rain, for the rain types defined in Table 4 were found. The volumetric contributions of raindrops with different diameters to the amount of the rain, assuming a constant rain rate are illustrated in figure 5. This result is a basic step toward to goal of generating artificial rains with features controlled and similar to natural rainfalls, using devices with narrower drop size distributions.

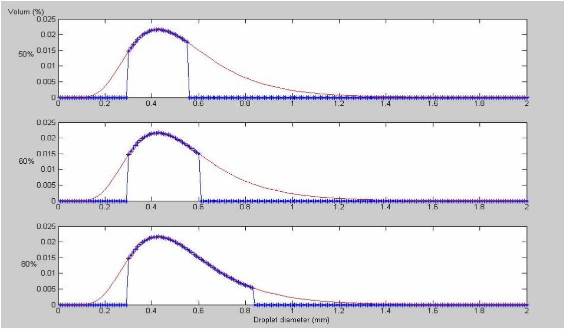

Figure 5. Volumetric contributions of raindrops with different diameters to the amount of the rain, assuming a constant rain rate.

V. CONCLUSIONS

Natural rains are characterized by a high degree of variability. Variability means that rain rate changes in time and space. So do the statistics of the rain. The phenomenon is non-stationary from a statistical point of view. Physical models and statistical analysis reveal several relations and correlations between rain parameters. Many environmental factors tend to influence the underlying laws, resulting in a chaotic behavior of the real rain system.

The present work proposed and simulated several working parameters of a rain generator being designed. Computer simulations carried out in the present work are a basic step toward generating artificial rains with controlled statistical parameters

Acknowledgements:

This work was supported by Siemens V.D.O. and the authors are especially grateful to Mr. Andreas Henning, head of RS dept.

VI. REFERENCES

1. Institutul National de Meteorologie si Hidrologie Instructiuni pentru observarea, indentificarea si codificarea norilor si a fenomenelor meteorologice. Text revizuit si completat (adaptat la cod synoptic FM 12-VII-SYNOP) – Institutul de Meteorologie si Hidrologie, Bucuresti, 1986.
2. J. Lavergnat and P. Gole: A Stochastic Raindrop Time Distribution Model, Centre d'Etude des Environnements Terrestre et Plane´taires, Velizy, France, 1997.
3. Joanneum Research, Austria http://www.distrometer.at/Sample_analyses.html
4. The Weather Almanac, July 2000 http://www.islandnet.com/~see/weather/almanac/arc2000/alm00jul.htm
5. Marshall, J. S., and W. McK. Palmer, 1948: The distributions of raindrop with size. J. Meteor., 5, 165–166.
6. A. R. JAMESON and A. B. KOSTINSKI , Spurious power-law relations among rainfall and radar parameters, RJH Scienti c, Inc., USA, Michigan Technological University, USA
7. Levin, Z., 1971: Charge separation by splashing of naturally falling raindrops. J. Atmos. Sci., 28, 543–548.
8. R.R. Rogers, A Short Course in Cloud Physics, 2 ed. Pergamon Press, 1979
9. H. Byers, General Meteorology, 3 ed. McGraw-Hill, 1959
10. Pruppacher and Klett, Microphysics of Clouds and Precipitation, (1978, Reidel, Boston)
11. Bringi, V. N., V. Chandrasekar, J. Hubbert, E. Gorgucci, W. L. Randeu, W. L. and M. Schönhuber, Raindrop Size Distribution in Different Climatic Regimes from Disdrometer and Dual-Polarized Radar Analysis Journal of Atmospheric Sciences, vol. 60, 2003, Issue 2, pp. 354-365
12. Fiser O., Schoenhuber M, and Pesice P.: First results of DSD measurement by videodistrometer in the Czech Republic in 1998–1999, Studia Geophysica et Geodetica, 46, 3, 485–505, 2002.