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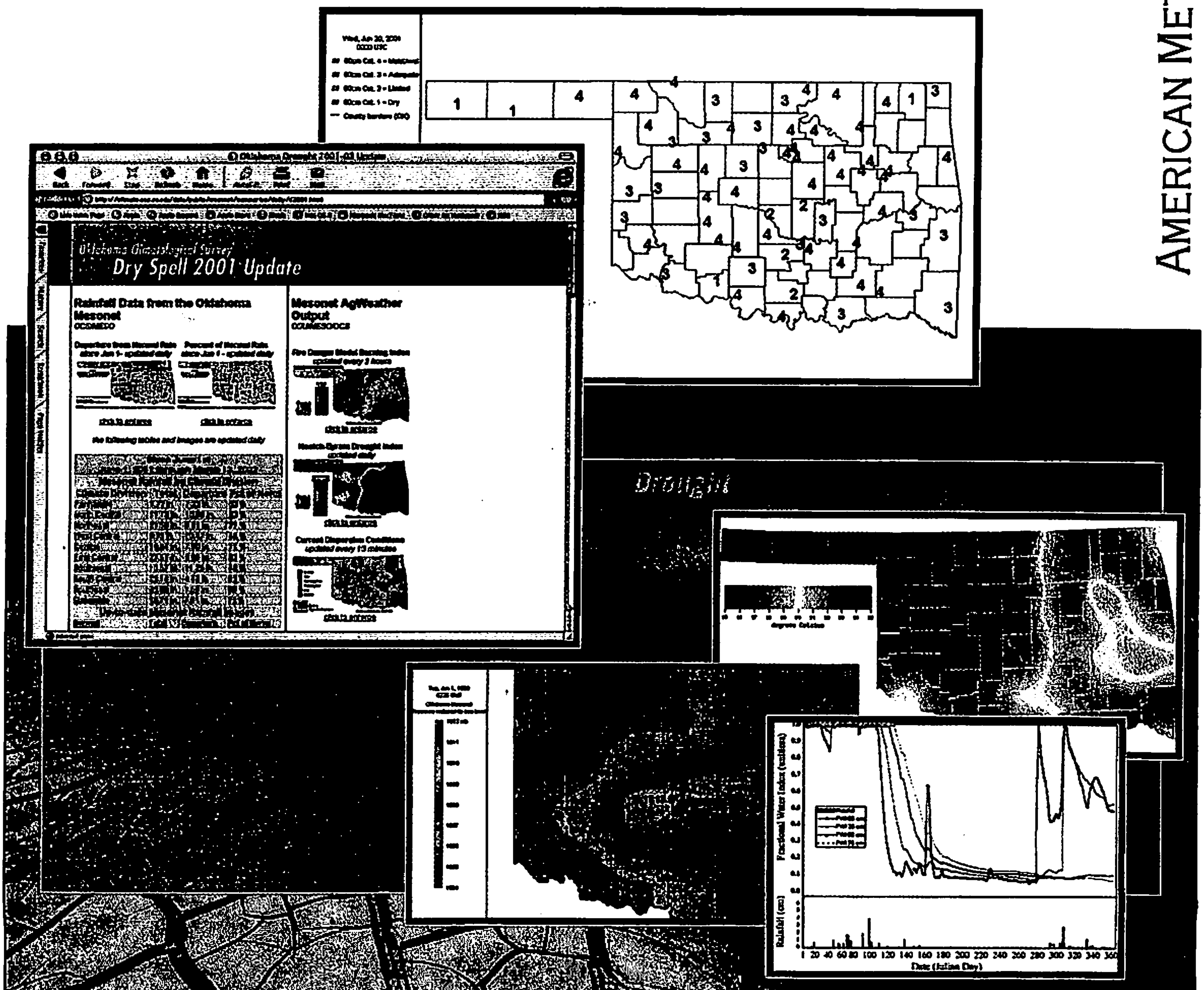

Oklahoma Mesonet

Stochastic daily rainfall generation in southeast Arizona

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I. INTRODUCTION

Thunderstorm rainfall in semiarid areas has a high degree of spatial and temporal variability. Knowledge of the spatial characteristics of thunderstorm rainfall is important for the increasing demands of distributed hydrological modeling. Rainfall data from the semiarid USDA-ARS Walnut Gulch Experimental Watershed (WGEW) are used to investigate the spatial characteristics of thunderstorm rainfall in southeast Arizona and to develop a daily thunderstorm rainfall generator.

II. DATA CHARACTERISTICS AND EVENT DEFINITION

The WGEW is located in the southeast Arizona, has an area of 150 km^2, and ranges in elevation from 1650 m in the east to 1200 m in the west. The rain gage network consists of 93 weighing bucket recording gages, which record cumulative depth of precipitation on a continuous time base. The period of record used for the analysis was 1960 to 1995 and consisted of 396 events. Events were screened such that days on which more than one event occurred were not included in the analysis.

III. ANALYSIS PROCEDURES AND RESULTS

The following statistical characteristics of daily thunderstorm rainfalls have been identified from an analysis of the WGEW data: the storm center locations on WGEW have a Poisson distribution, the maximum depth within a storm cell has a lognormal distribution, the shape of a storm cell is elliptical with an average major axis length to the minor axis length ratio of 1.55 and the orientation of a storm cell is primarily NW or NE. The storm coverage and the maximum rainfall depth within a storm cell have a linear relationship after a logarithmic transformation. Storm occurrences have higher frequencies during the last two weeks of July and the first two weeks of August than other wet periods (July ~ September).

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Tables 1-3 summarize the statistical characteristics of the WGEW data. The results included here are limited to a summary of the analysis; more results are available from the authors.

Table 1 Summary of statistical tests for daily thunderstorm rainfall characteristics

	Test method	Test statistic t	Test critical value	Test result
Location of storm center	Nearest Neighborhood function	1.25	1<t<2.25	Poisson distribution
Maximum depth within a storm cell(mm)	K-S test	0.593	t<1.096	Lognormal distribution

Table 2 Summary statistics of selected events: mean and standard deviation(std)

	mean	std
Storm orientation	91.4° form the West	38.3°
Ratio of major to the minor axis of storms	1.54	0.37
Storm coverage (km^2)	50	39
Max depth within a storm cell(mm)	10.7	3.24

Table 3 Bi-weekly transition probability (%): probability of wet (Pw), probability of dry (Pd), probability of wet given a previous day wet (Pw/w), Probability of dry given a previous day dry (Pd/d)

Period	Pw	Pd	Pw/w	Pd/d
Jul 1-15	56	44	69	61
Jul 16-31	79	21	82	35
Aug 1-15	67	33	76	51
Aug 16-31	55	45	65	61
Sept 1-15	51	49	67	66
Sept 16-30	25	75	56	86

The bi-weekly stochastic daily summer rainfall generator was developed based on the statistical characteristics derived above. The daily thunderstorm rainfall generation processes involve the following steps:

Step 1: Generation of a dry and wet sequence using bi-weekly transition probabilities.

Step 2: For each wet day, generate a random distributed storm center location.

Step 3. Generate a maximum storm depth (d) within a storm cell for each event using a lognormal distribution with an upper limit set as the mean + 1.625 times the standard deviation.

Step 4. Calculate relative storm areal coverage (A) using a relation between storm coverage (in Km^2) and maximum rainfall depth (in mm) within a storm cell plus a random term: $A = 33.4 * d^{1.7} \pm 64.67 *$uniform deviate.

Step 5. For a given areal coverage (A), calculate the lengths of the major and minor axes using the ratio determined above ($1.55 \pm 0.37*$ uniform deviate).

Step 6. Calculate storm orientation for each event using the mean plus a random term ($91.4 \pm 38.3 *$ normal distribution deviate)

Step 7. Calculate rainfall depth values on desired locations for each storm using an exponential spread function.

The rainfall generator was tested by comparing the simulation results with long-term historical records of representative gages on WGEW. The following is a summary of the comparisons for the bi-weekly period July 16-31.

The observed and simulated wet day probabilities for the entire watershed are the same (Table 4).

Table 4 Probability (%) of wet days for entire watershed: observation and simulation

Period	Observation	Simulation
Jul 1-15	56	56
Jul16-31	79	79
Aug 1-15	67	67
Aug 16-31	55	54
Sept. 1-15	51	51
Sept. 16-30	25	24

However, for each individual gage, the simulated probabilities are consistently lower than observed probabilities. There are two possible reasons for this tendency: First, the model uses a cutoff value to eliminate small events from simulations. However, the observed wet days of each individual gage were counted whenever there was any trace of precipitation during a day. Therefore, the observed probability of wet days on each individual gage tended to be underestimated by the model. Second, the model used a regular shape (elliptical) to represent the spatial extent of storm. However, most observed storm shapes were irregular, the model tended to catch fewer events around the edges of simulated storms.

Figure 1 is the simulated and observed cumulative distribution function (CDF) of the maximum rainfall depth within a storm cell. The simulations reproduce close representation of CDF compared to the observations. Non-parametric tests also indicated both CDFs have lognormal distributions.

Figure 2 presents a comparison of the observed and simulated average rainfall depths on selected gages with elevation. The average rainfall depth is the sum of the rainfall depths from selected or simulated events divided by the number of events. The upper and lower limits are the average of rainfall depth with 95% confidence intervals. All simulated average rainfall depths fall inside the 95% confidence intervals. The simulations near the watershed boundary (near the east and west edges of the watershed) have larger differences with the observations due to lack of rainfall information near the edge.

IV. DISCUSSION AND CONCLUSION

The stochastic daily rainfall generator produces good approximations of the daily thunderstorm rainfall in WGEW. The simulations near the watershed boundary have large errors due to edge effects. Since some rain gages fall outside of the watershed boundary, the edge effects can be eliminated by applying the simulated results inside the watershed boundary. The spatial daily thunderstorm generator can provide inputs to distributed hydrological modeling for advanced study.

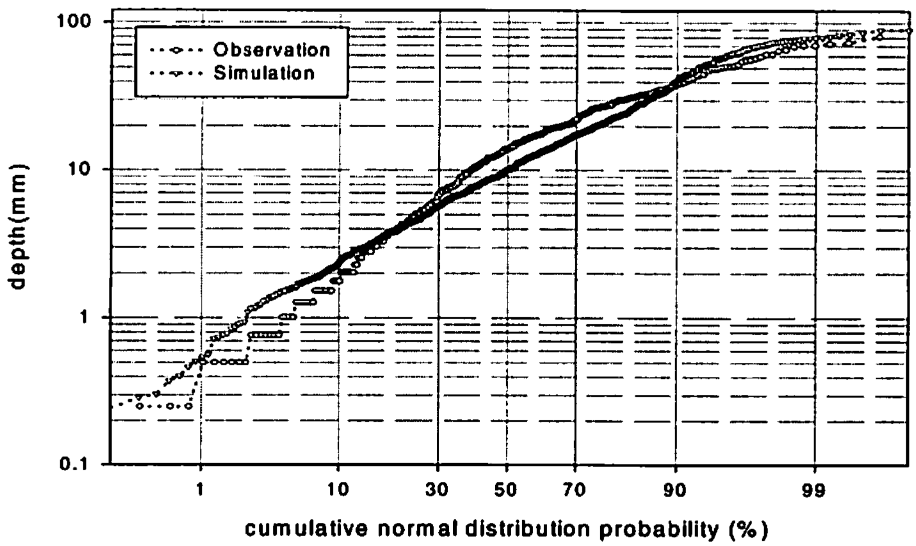

Figure 1 Maximum depth within a storm cell CDF plot : July 16 - 31
Plotting position formula used: Weibull's formula

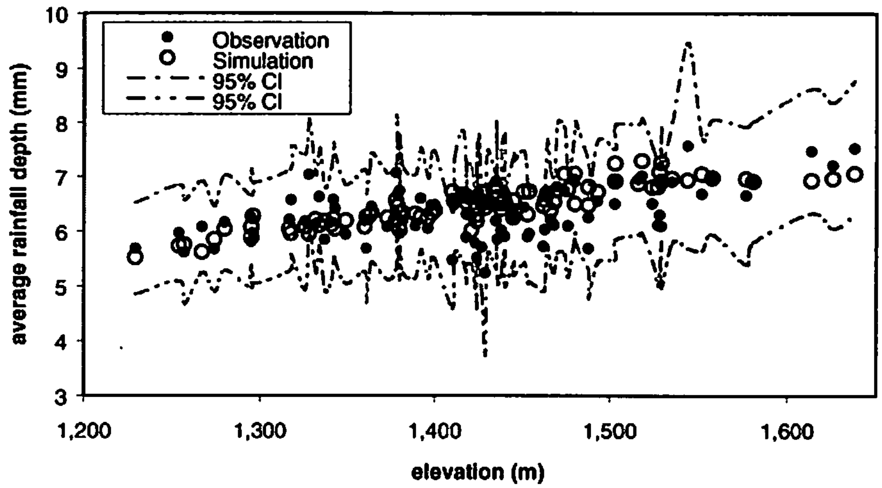

Figure 2 Rainfall simulation and observation: average rainfall depth (mm)
Simulation period: July16-31