Synthetic Storm Creation in Flatland Pampa Ondulada Region

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Abstract. The critical floods on flatland areas are generally the result of successive rainfall events. The object of this paper consists in the synthetic construction of storms series with similar characteristics that measuring events. The data were analysed by means of five variables: the duration of the rain, the time between events, a half and maximum intensity of the rain and the storm advance coefficient. At first place, the variables were classified in independent and dependent ones. Probability distribution functions (pd.) were fitted for the independent variables. Multiplicative relationships were proposed for dependent variables and its coefficients were adjusted previously. A methodology was proposed in order to generate a synthetic series of storms of twenty years long. Finally, the statistical characteristics of the synthetic series were calculated and compared with the data series characteristics. A good agreement between calculated and measured series is obtained.

INTRODUCTION

The hydrological systems placed in flatland areas presents typical responses to the precipitation, which are differents of the other systems. These systems are very vulnerable to persistent precipitation, which could generate more critical floods than short rainstorms with great intensity. Therefore, it is necessary study the behaviour of regional rainstorms and so find their particular characteristics and they reproduction, if the case requires it, of synthetic way. It in a previous phase have been carried out a characterisation of the storms of the region, analysing frequency histograms of the main variables that define the event (Navarro, Zimmermann, Silber, 1996).

DATA

The rain recorder used in this work, named 'Sapucay ' gage, is located near to Alcorta City, County of Santa Fe, Argentina. (Fig 1). The intensities data and date and hour of events were organised in a data base. The rain record had five years long (*1979-1985*). Therefore, the hietograph were constructed with half hour interval. A independent rainstorm was considered when it have separated a lapse of one hour of the others, say two intervals without rainfall. Rainstorm of minor to 1 mm. and those with duration less than one hour were excluded. After this depuration, the amount of events remained reduced to 301 cases, of which it corresponded to 106 summery storms, 47 autumnal, 38 winters and 100 spring.

METHOD

Analysis of data . To the goal of generating a series of events it was necessary, first, analyze the temporary sequence between rains and, in second term, the characteristics of each individual event. The sequence was evaluated with the intervals of time between storms. This variable, t_{ll}, implied the subtraction between dates and hours of beginning of storms. The rain characteristics were studied analyzing their duration, d_{ll}, the maximum intensity, i_{mx} ,and average intensity, i_{av} ,and the time position of maximum and duration ratio (advance coefficient, c_{av}). The variables characterization was analyzed by means of frequency histograms and the main conclusions (Navarro, Zimmermann, Silber, 1996) were: a) The advance coefficient have shown a normal statistical distribution with light asymmetry toward left and remainder variables have shown a exponential statistical behaviour; b) To exist some irregularities for d_{ll} in winter (bimodal behaviour) and, generally, autumn and winter presents major deviations. c) A combined analysis of frequencies pointed out a inverse correlation between advance coefficient and duration of the rainstorm. Therefore, were carried out simple correlations among variables, under several formulations (linear, multiplicative, exponential and reciprocal). The coefficients of higher correlation were obtained for multiplicative regressions between i_{mx} -i_{av} ($0.616 < r < 0.886$) and d_{ll} -c_{av} ($0.560 < r < 0.612$).

Model proposed. Generating of the model of storms implied the proposal of a methodology to determine the value of the five variables that they characterize them. Based on the results of the previous phase, it was selected three independent variables (t_{ll},, d_{ll} and i_{av}) and two dependent variables (i_{mx} (i_{av}) and $c_{av}(d_{ll})$). The formulation of the model consists, then, in determining the independent variables by mean of aleatory numbers generated with statistical adjusted distributions next to the two dependent variables generated starting from the equations of regression. Four *pdf* on the three independent variables for each season were proven. The applied laws were exponential, gamma (2-parameters), lognormal and Weibull distributions. The Gamma function was adopted for t_{ll} in summer, winter and spring; for d_{ll} in spring and for i_{av} in summer. The lognormal function was selected for t_{ll} in autumn; for d_{ll} in summer, autumn and winter and i_{av} in autumn and winter. Finally, the Weibull distribution have represented better i_{av} in spring. It is observed an evident prevalence of the Gamma and lognormal laws on the remaining.

Since the multiplicative regression, from type $Y=a\,X^{b}$, it was the best correlation among the variables, the same was adopted to calculate the dependent variables (Table 1). It was carried out a statistical analysis of the residuals, determining its variance. The residuals was considerated as *white noise*, with normal distribution and null average. Synthetic series of errors, with the same statistical propierties, were generated and were added to the values of the dependent variables obtained by correlation.

RESULT AND DISCUSSION

Twenty years of precipitation were generated with the previous procedure, which they were separated by seasons. The fact of generating external variables, such like the intervals between storms, allowed to generate the sequences of rains, while the generation from internal variables, such like intensities, duration and advance coefficients, it have permitted reproducing hietographs, adopting a triangular time distribution with steps of time to election. The sequences were classified in four quinquennials of annual series of storm, which it were statistically analyzed in order to confront with the series of data (Table 2). The following were observed:

1. The intervals between rains for the annual series demonstrate that the number of storms per year oscillate between 60 and 70, manifesting an important correlation with the general frequencies of rains observed. Also, the synthetic module annual (1021 mm) was very near to it observed (1000 mm.) in the region.
2. The coefficients of advance of the storms don't present a great variability seasonal or annual. The winters series are those that they show greater dispersions of the results, like of data..Taking an interval of ± 10% around the average values of data could be affirmed that the springs and the winters showed 8 cases outside of this interval, autumn with 6 cases and finally summer with 4 cases. Generally, the standard deviation between simulated series and

data were similar. Lamentably, space reasons permit not published the Table 2 completely, including the seasonal results.

In relation with the temporary distributions of the storm intensities, there it was studied, seasonal and annually, the relationships between i_{mx} and i_{av}.. A triangulate shape for a hietograph imply that the named distribution coefficient $c_{di} = i_{av} / i_{mx} = 0.5$, since $i_{mx} * d_{ll} /2 = i_{av} *d_{ll}$. This relationship between intensities, it were evidenced by the regression coefficients (Table 1), where the exponent $\boldsymbol{b}$ is near to the unit (linear relationship), in addition to $\boldsymbol{a} = \boldsymbol{c_{di}^{-1}}$ is near to 2. The distribution of frequencies of c_{di} was analyzed in the annual and seasonal series of the data. The Fig. 2 show the relative frequencies of c_{di} for each case. Can be looked a strong tendency of the storms to it distribute in triangulate shape (c_{di} =0.5), although a minor portion of the same spreads to the forms of hyperbolas (c_{di} = 0.3), to the Chicago style. In spite of these deviations were considered, in consequence, that a triangular distribution constitutes a simple and representative tool.

CONCLUSION

The synthetic series of storms obtained it behave statistically of the same form that the observed series. The same behavior is observed for the seasonal series except for the winter, which greater deviation in their results, probably due to the minor amount of events that compose, being it the driest season of the year. In consequence, the methodology in order to generate sequences synthetic of storms is reliable and could be used, between other uses, in order to analyze the vulnerability from hydrological systems by means of the operation of rainfall-runoff models.

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Table 1. Coefficients, exponents and correlations of multiplicative relationships.

dependent variables	i_{mx} summer	i_{mx} autumn	i_{mx} winter	i_{mx} spring	c_{av} summer	c_{av} autumn	c_{av} winter	c_{av} spring
Coeff a	2.01363	2.01215	1.85127	2.18306	0.53504	0.61701	0.63716	0.55233
Expon b	1.06464	1.01204	1.0793	0.9805	-0.19363	-0.46471	-0.25871	-0.2717
Correlation. Coefficient.	0.9196	0.9300	0.9043	0.9035	-0.2043	-0.4235	-0.2138	-0.2766
Variance of residual	0.41594	0.41353	0.42280	0.42497	0.63156	0.68942	0.77682	0.62678

Table 2. Means and Standard Desviations for annual series

Mean & Deviations	t_{ll} (hs)	d_{ll} (hs)	i_{av} (mm/h)	i_{mx} (mm/h)	c_{av} (adim)
ANNUAL					
Data	120.10±188.93	3.80±2.69	3.81±3.66	8.86±9.19	0.44±0.24
1st Quinq.	149.10±266.84	3.49±2.69	4.18±4.10	9.01±9.21	0.46±0.39
2nd Quinq	137.60±195.49	3.63±2.49	3.54±3.60	7.66±7.86	0.42±0.40
3th Quinq	123.39±178.62	3.67±2.79	3.79±3.68	8.22±8.11	0.46±0.39
4th Quinq	129.33±282.86	3.67±2.72	4.00±4.19	8.66±9.25	0.46±0.40