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PERSISTENCE IN SURFACE OVERFLOW OF ANDEAN RIVERS

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ABSTRACT

The temporal structure of both deficit (negative) and excess (positive) periods in surface overflow of Andean rivers were analyzed by studying the runs.
In Southern areas (in the province of Neuquén and the Southern part of the province of Mendoza), positive and negative groups of anomalies have been found to diminish geometrically over the years. In the Northern areas (in the province of San Juan and Northern part of the province of Mendoza) persistence occurs in negative runs only. This behaviour is produced by the influence of the basins located in an arid zone, because of the heterogeneity in the structure of the precipitation in this region.

RESUMEN

En este trabajo se analiza el comportamiento de la persistencia en el escurrimiento superficial de los ríos andinos, usando el método de rachas de eventos con anomalías positivas o negativas.
Se ha encontrado que las rachas positivas o negativas tienen en la zona más austral (provincia de Neuquén y sur de Mendoza) un decaimiento de tipo geométrico con los años; en cambio hacia la zona más septentrional (provincia de San Juan y norte de Mendoza) aparece la persistencia solamente en las rachas negativas o de sequías. Este comportamiento no se encuentra en la estructura de la precipitación que cae en la cuenca, por lo tanto se infiere que el mismo sería debido a la regulación que ejercen las cuencas del norte, inmersas en una región de clima árido.

1. INTRODUCTION

As a result of the severe drought registered in the Andean rivers of the Central Cordillera during the late 60s and early 70s in the provinces of San Juan and Mendoza (Argentina), a great research effort was directed towards understanding the nature of this phenomenon. Basic hydrologic studies were conducted to understand the interannual variability regime of both river overflow and rainfall (Menegazzo et al., 1985; Carletto et al., 1985, 1987; Minetti et al., 1989). In addition, the interaction between regional atmospheric circulation, rainfall and river overflow have also been studied by Minetti et al. (1982), Minetti and Sierra (1989) among others.

One of the most relevant aspects involved in the structure of the overflow time series of central Andean rivers is the persistence in change exhibited by annual events of rivers located to the north of this group, which can be geographically placed in the Northern part of Mendoza and San Juan provinces (Carletto et al., 1985). Due to recent droughts (in the 80s), this subject is once more under study. The objective is to probabilistically estimate the continuation of a negative event when a similar episode, although of different length, has previously occurred.

Similar studies were performed in other areas by Downer et al. (1967), Saldarriaga and Yevjevich (1970) among others.

The obtained results will be most important for the utilization of reservoirs and regulation of available water.

2. DATA AND METHODS

The series of annual overflows of Andean rivers, from Jachal to Limay rivers, supplied by Agua y Energía Eléctrica (1981) and by the Department of Hydraulics of San Juan province, for the 1909-86 period, were used for the analysis.

These series were transformed into stationary series of the first order by eliminating their respective tendencies with second degree polynomial smoothing (Brooks and Carruthers, 1953; Yevjevich and Jeng, 1967, 1969). In all cases the least squares method was used. This technique prevents the possibility of finding either positive or negative prolonged anomalies. Next, the number of events showing values above or below this tendency -which was regarded as normal value- were estimated. Such events or runs were afterwards evaluated as a function of time as one-, two-, three-year runs, or more, according to Yevjevich (1972). In agreement with the same author and Mood (1940), the distribution of events or runs has been smoothed to a geometric type model, assuming that each event (+ or -) is independent of the other.

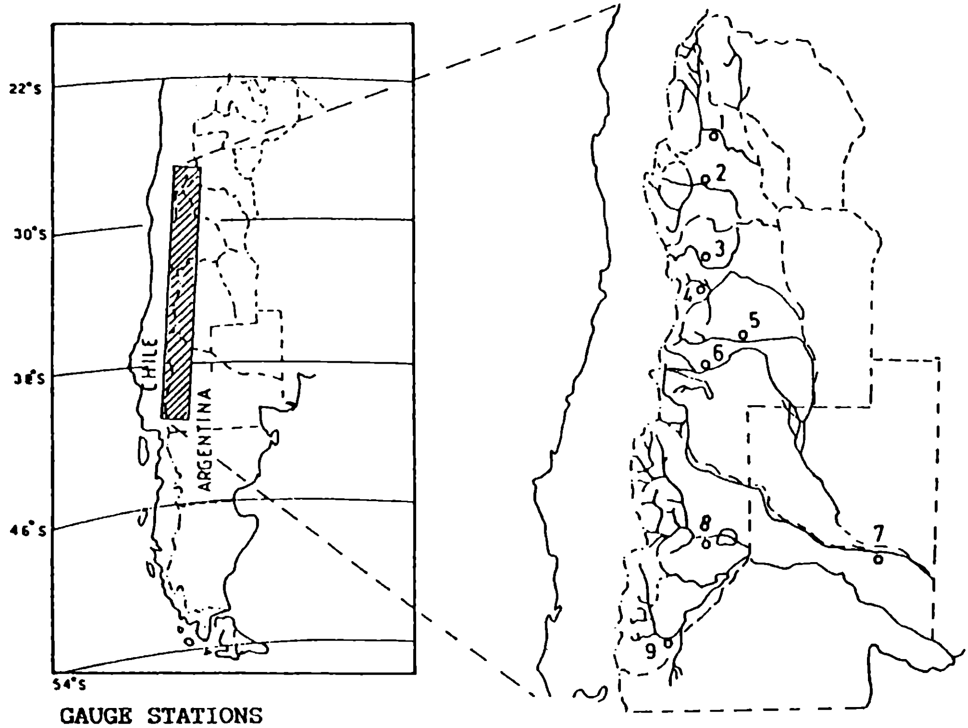
3. RESULTS AND DISCUSSION

Figure 1 shows the area under study, and the river basins listed in Table I. According to Carletto et al. (1985) 55% of Central Andean rivers, from the Limay to the Jachal, show significant autocorrelations at the first lag (lag 1), while their autocorrelation at the second lag (lag 2) corresponds to the criterion of $r_1^2 \approx r_2$ approximately. This allows us to infer that these processes are persistent and in a first approach respond to an autoregressive model of the first order. In other words, persistence or inertia to changes exists in more than half of these rivers, especially in the Northern ones located in an arid zone.

In addition, a previous work by Carletto et al. (1987) reported that river overflows in the Northern arid zone were less aleatory, with an increment of deterministic components (tendencies to jumps) that deserved further investigations. One of these deterministic components is a secular tendency, which is mainly present in Northern rivers. In this case, the secular tendency has been filtered prior to the analysis of runs.

Persistence remains in the structure of these time series and events are more frequent in deficit (negative anomalies) than in excess overflow (positive anomalies). Rainfall series have not a similar behaviour. Minetti and Carletto (1990) reported that the area involved was affected by the dominance of fast changes (high frequencies) in the interannual rainfall variability with dominant oscillations below five years, which were incompatible with persistence.

Drought episodes occurring in the late 80s reopened this matter, showing the importance of evaluating the probability of occurrence of consecutive deficit or excess overflows, in order to use this information in agriculture and energy requirements.



GAUGE STATIONS

1- Pachimoco (Jachal River)
2- Km 47 (San Juan River)
3- Usina Cacheuta (Mendoza River)
4- Valle de Uco (Tunuyan River)
5- Los Reyunos (Diamante River)
6- La Angostura (Atuel River)
7- Pichi Mahuida (Colorado River)
8- Paso de los Indios (Neuquén River)
9- Paso Limay (Limay River)

FIGURE 1. *Map of the study area. The location of the gauge stations for the Andean rivers is also shown.*

RIVER	Basin Surface Km^2	Gauge Station Location	Years Records
JACHAL	25,500	$30^o13'S; 68^o50'W$	51
SAN JUAN	25,670	$31^o13'S; 68^o63'W$	74
MENDOZA	9,040	$33^o01'S; 69^o07'W$	71
TUNUYAN	2,380	$33^o47'S; 69^o15'W$	66
DIAMANTE	4,150	$34^o34'S; 68^o34'W$	47
ATUEL	3,800	$35^o02'S; 68^o52'W$	74
COLORAD	22,300	$38^o50'S; 61^o50'W$	62
NEUQUEN	30,200	$38^o32'S; 69^o25'W$	76
LIMAY	26,400	$40^o32'S; 70^o26'W$	77

TABLE I.. *Some hydrological and geographical characteristics of the studied rivers*

Positive (excess) and negative (deficit) runs of the observed overflow are shown in Tables II and III; they are also plotted in figure 2. From these, it can be seen that excepting Jachal, San Juan and Mendoza rivers, all of them located in the Northern region, Andean rivers exhibit an important drop in the frequency of occurrence of long runs. The mentioned rivers are located in the most arid zone, where two and three-year negative runs prevail.

Figure 3 shows frequency of occurrence of runs with lengths equal to or above those specified in the abscissas (in years) for negative events, compared with a theoretical geometric model according to eq. (1), Yevjevich (1972).

$$f(x) = q^{(x-1)}\, p\ (1) \qquad (1)$$

where:
q = frequency of occurrence of a negative or positive event
p = 1 - q
x = length of runs in years

RIVER	1	2	3	4	5	6	7	8	9	TOTAL (+)
JACHAL	3	2	1	1	0	0	0	0	0	14
SAN JUAN	9	6	0	1	1	0	0	0	0	30
MENDOZA	8	4	1	0	0	1	0	0	0	25
TUNUYAN	9	4	0	1	0	0	0	0	0	21
DIAMANTE	2	1	0	2	1	0	0	0	0	17
ATUEL	8	5	1	1	1	0	0	0	0	30
COLORADO	9	7	1	0	0	0	0	0	0	26
NEUQUEN	7	7	2	0	0	0	0	0	1	39
LIMAY	8	5	3	1	1	0	0	0	0	36

TABLE II.. *Set of positive runs (excess).*

RIVER	1	2	3	4	5	6	7	8	TOTAL (-)
JACHAL	1	0	3	0	0	1	0	1	24
SAN JUAN	3	5	4	2	1	1	0	0	35
MENDOZA	5	1	5	1	0	2	0	0	38
TUNUYAN	5	4	2	1	1	1	0	0	28
DIAMANTE	2	0	0	1	1	0	0	1	19
ATUEL	6	5	3	1	2	0	0	0	39
COLORADO	9	4	2	1	1	0	0	0	32
NEUQUEN	8	6	1	1	0	0	1	0	34
LIMAY	8	5	3	1	0	1	0	0	37

TABLE III. *Set of negative runs (droughts).*

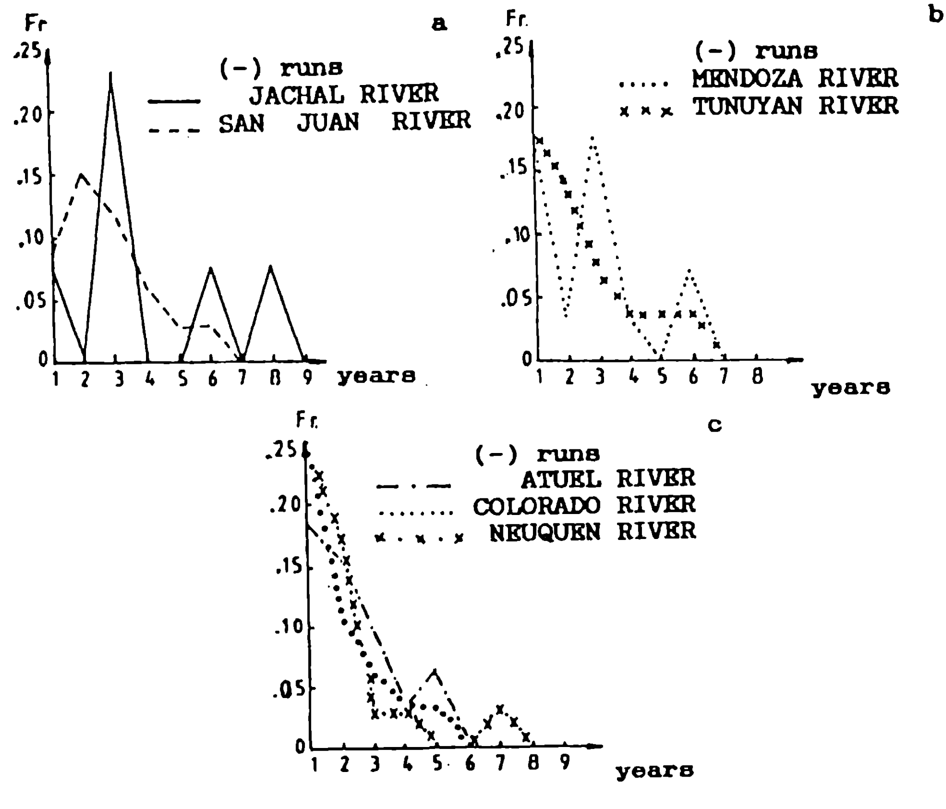


FIGURE 2. *(a): Relative frequencies of negative runs in Andean rivers of the Northern Central Cordillera; (b) Central part of Central Cordillera; and (c) Southern of the Central Cordillera.*

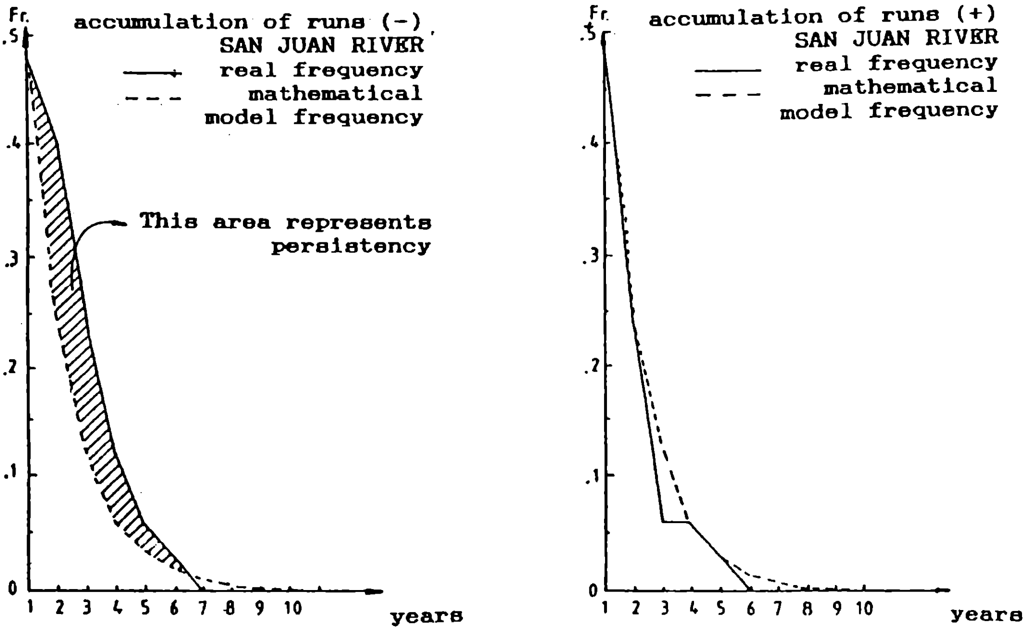


FIGURE 3. *(a): Accumulated relative frequencies of negative runs, with lengths equal to or above those specified in abscissa axis for San Juan river, in the North of the study region; (b) accumulated relative frequencies of positive runs.*

Figure 3 also shows that negative runs of San Juan river have higher probabilities than those obtained by applying the theoretical method that assumes the independence of events. This fact is not observed when dealing with positive runs. This loss of randomness resulting from an increment of persistence would be, in the case of negative runs, the component transforming from normal to log-normal or exponential, all of them models of distribution of overflow occurrence in Andean rivers, from South to North (Carletto et al., 1987). Figure 4 shows that negative runs of Neuquén rivers fit very well with the observed data, in such a way that a statistical verification test is unnecessary.

In several works, it has been reported that Northern basins exhibited an important water retention and subsequent regulatory behaviour. This is particularly valid in the case of large excess events such as those observed in the hydrological cycles of 1921-22 and 1941-42. However, in an arid zone similar to the one described here, one year with little water excess following a long drought period, does not suffice to replenish water level in the basin, and drought conditions continue to be manifested in the overflow.

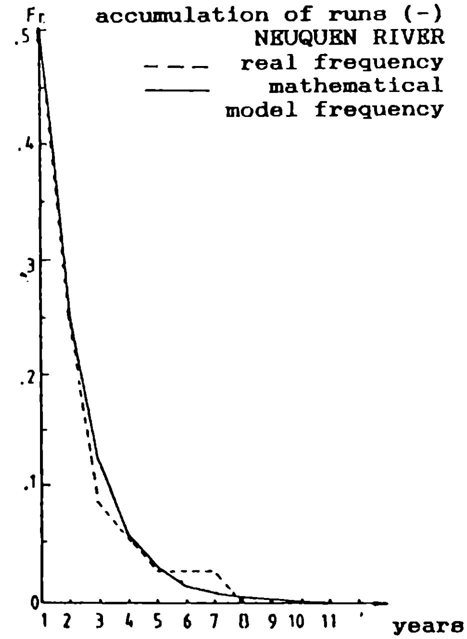


FIGURE 4. *Relative frequencies equal to or below those specified in abscissa axis, for Neuquén river in the South of the study region.*

4. CONCLUSIONS

From the results obtained it can be concluded that:

1- No persistence is observed in positive runs (excess) in Andean rivers. In general these events occur separately.
2- Negative runs (deficits) involve an increment in persistence from South to North.
3- Negative runs prevail in the Northern region with two or three year groups.
4- The persistent behaviour of droughts, and the non stationarity (tendencies) in the overflow of Northern rivers, would be the causes of randomness loss in the structure of data series.

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