Some Aspects of Argentine Rainfall

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Abstract

This report investigates at first what percentage of the number of days with rain accounts for most of the rainfall in widely separated climatic provinces of Argentina. It turns out that this percentage, which may be termed the relative precipitation intensity, is a constant in space and time.

Then the frequency distribution of natural rainfall periods (rainstorms) is analysed in relation to the rainfall derived from these disturbances. It is found that the same percentage of the rainstorms accounts for the same large fraction of total rainfall regardless of season or geographical effects.

It is well known that average annual or monthly precipitation values at any station fail to give some of the most important information wanted from such data. In particular, frequency distributions of rainfall amount over any time interval seldom, if ever, follow the Gaussian law of normal distribution but are skewed. The number of days (or months) with rainfall below average exceeds those with rainfall above average. Large seasonal and regional differences of skewness, however, are to be expected. It is of practical importance to know these differences and to determine the number of days that account for the bulk of the rainfall at any location.

This report gives the result of computations made with this objective for different climatic provinces of Argentina. In order to hold the statistical labor within feasible limits ten characteristic areas were selected (fig. 1). Within these areas, the rainfall was analyzed by means of the daily rainfall values given in Carta del Tiempo published by the Argentine Meteorological Service. The study covers five years, 1944—1948, a sufficient statistical sample for the present purposes.

The selection of the ten areas shown in fig. 1 was partly dependent on the following consideration. Analysis of rainfall data taken at a particular rain-gage often is of restricted value only. Such data on many days may not be representative even for the surroundings of the gage, especially when the clouds are cumuliform. Integration over several closely adjoining gages is preferable. For this reason, it was attempted to locate groups of ten stations situated near each other and climatically as uniform as possible, especially with regard to monthly and annual rainfall. This objective was readily realized in such provinces as Buenos Aires, but necessarily could not be satisfied fully in the mountainous and sparsely settled regions. In the far south, it was not possible to form a group. There, five stations were treated separately.[1]

Fig. 2 shows the mean annual rainfall of Argentina. It is readily seen that in spite of the difficulties in selecting material it was possible to locate nine zones consisting of 10 stations each in climatic regimes that vary widely as concerns latitude, proximity to high mountains or coast, dynamic regime and total precipitation. Table 1 gives the average seasonal precipitation measured in each zone during the 5-year interval, and Table 2 gives the corresponding number of days with rain.

Rainfall analysis

The analysis procedure was as follows: At first, the average precipitation was determined for each day of the 5-year period in each zone. Then these daily values were written

[1] The names of all stations utilized in this report appear in an appendix at the end of the report.

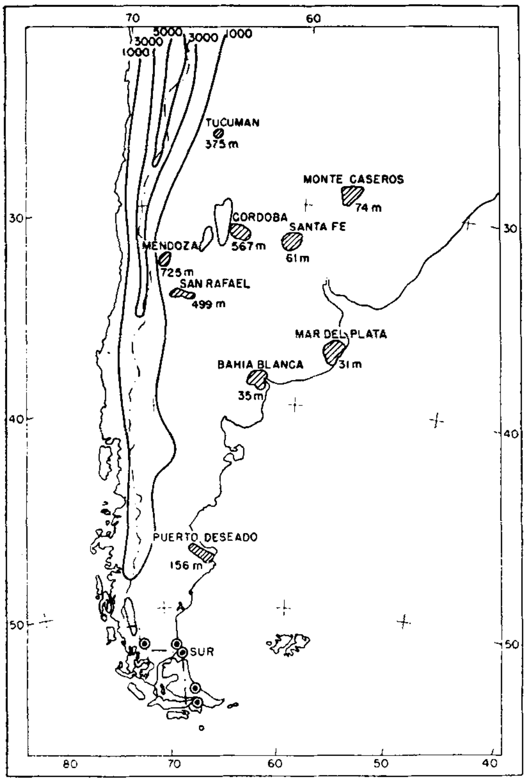

Fig. 1. Principal topographic features of Argentina, and location of the zones used in study (mean elevation of each zone in m).

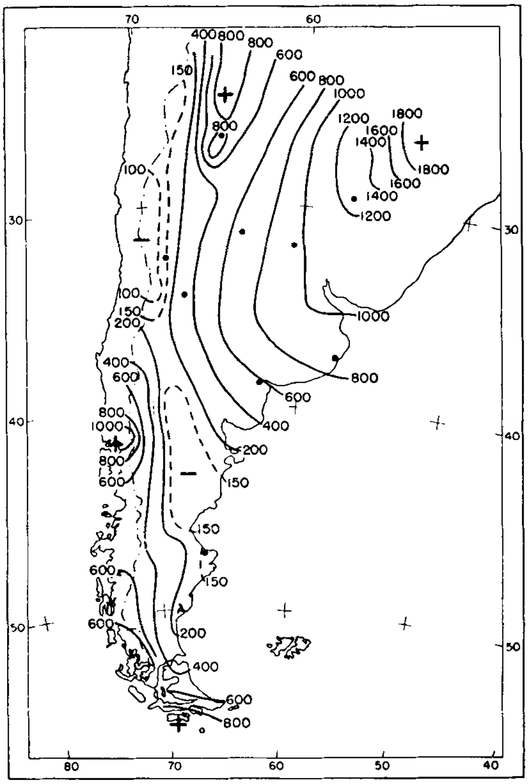

Fig. 2. Mean annual rainfall of Argentina (mm).

in ascending order of amount on a monthly basis (for 5 Januaries, 5 Februaries, etc.) and both rainfall and number of days with rain were summed on a cumulative basis. Finally, all cumulative subtotals were expressed in percent of the totals. Following is an illustration of this computation scheme (not based on actual data).

Table 1. Mean seasonal and annual rainfall (mm) for 1944—48 in each zone and at the southern stations El Turbio (52° S, 72° W) and Ushuania (55° S, 68° W).

Zone	Jan.—Mar.	Apr.—June	July—Sept.	Oct.—Dec.	Year
Tucumán	350	76	11	194	631
Monte Caseros	319	335	250	341	1,245
Santa Fé	332	143	77	230	782
Córdoba	226	66	36	213	541
San Rafael	120	47	24	69	260
Mendoza	89	13	24	48	174
Mar del Plata	200	197	157	153	707
Bahia Blanca	97	78	94	114	383
Puerto Deseado	19	22	27	13	81
El Turbio	33	43	50	35	161
Ushuaia	142	127	100	123	492

Table 2. Mean seasonal and annual number of days with rain, 1944—48, in each zone and at El Turbio and Ushuaia

Zone	Jan.—Mar.	Apr.—June	July—Sept.	Oct.—Dec.	Year
Tucumán	34	17	8	25	84
Monte Caseros	33	26	26	24	109
Santa Fé	31	21	16	29	97
Córdoba	30	13	9	29	81
San Rafael	22	8	7	17	54
Mendoza	18	7	7	15	47
Mar del Plata	35	34	37	34	140
Bahia Blanca	25	17	17	31	90
Puerto Deseado	14	16	19	11	60
El Turbio	8	7	7	7	29
Ushuaia	36	30	26	31	123

Cum % days with RR	No days cum	RR (mm)	Cum RR (mm)	Cum % RR
8	1	1	1	1
17	2	1	2	2
25	3	2	4	5
33	4	3	7	8
42	5	3	10	12
50	6	4	14	17
58	7	6	20	24
67	8	7	27	32
75	9	9	36	43
84	10	12	48	57
92	11	16	64	76
100	12	20	84	100
Totals 100	12		84	100

Following completion of the computation sheets, the results were plotted on graphs with cumulative percent of the number of days with rain and cumulative percent of rainfall as axes (cf. figs. 4,11). From these graphs it is possible to determine what percentage of the total rain falls during what percentage of the number of days with rain. In order to study seasonal and regional variations, is was convenient to investigate certain significant percentages only. From the appearance of all curves it was clear that a study of the levels 50 % and 75 % of the precipitation (measured downward from 100 %) would bring out the significant features of the distribution. Figs. 3 a, b show the seasonal trend of these two levels in two of the zones, which are widely separated geographically and situated in entirely different rainfall regimes. The graphs say that 50 % of the rainfall is accounted for by less than 20 % of the number of days with rain, and 75 % of the rainfall is accounted for by less than 30 % of the number of days with rain. Neither zone has a regular seasonal trend and exhibits only minor irregular fluctuations. As figs. 3 a, b are typical for all zones, *it follows that the relative concentration of rainfall is independent of season in Argentina.*

Table 3 shows the annual means and mean deviations of the two precipitation levels for all zones. For this purpose, the results for the five stations of the southernmost zone could be combined, since they were practically identical. *It turns out that the percentages are practically independent of geography, rainfall regime and total rainfall in addition to season,*

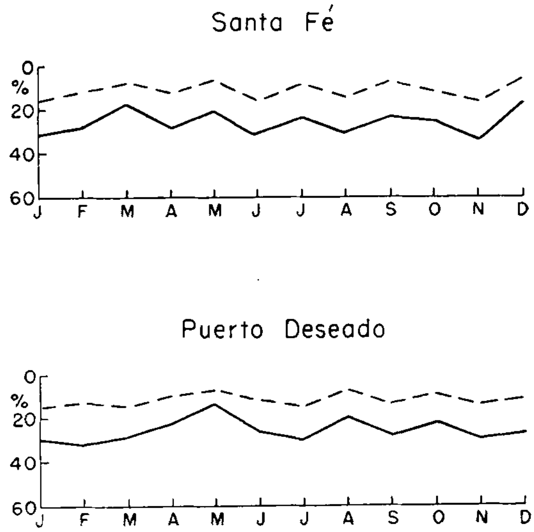

Fig. 3. Seasonal distribution of the percent number of days with rain (ordinate) that account for the indicated percentages of the monthly precipitation for two zones.

especially for the 50 % rainfall. The extreme rainfall regime of southern Patagonia and Tierra del Fuego proves the only exception, and even there the departure is small at the 50 % level.

Fig. 4 gives the composite curve for all zones combined. This curve can be closely approximated by the analytical expression.

$$y = axe^{bx}, \qquad (1)$$

Table 3. The percentages of the number of days with rain that account for 50 % and 75 % of the annual precipitation in each zone and in all zones combined. The mean deviations refer to the departures of the monthly values (as shown in fig. 3) from the annual mean in each zone.

Zone	50 % of total precipitation		75 % of total precipitation	
	Mean	Mean deviation	Mean	Mean deviation
Tucumán	12	3	25	6
Monte Caseros	13	2	27	4
Santa Fé	13	2	27	4
Córdoba	13	2	28	4
San Rafael	15	3	32	4
Mendoza	15	5	29	7
Mar del Plata	12	2	25	4
Bahia Blanca	12	4	26	5
Puerto Deseado	12	3	27	5
Sur	20	2	41	3
Mean for all zones	14	3	29	5

where y is the rainfall expressed in cumulative percent of the total, x the number of days with rain expressed in cumulative percent of the total, and a and b are constants ($a = 2.30 \cdot 10^{-2}$, $b = 3.78 \cdot 10^{-2}$). This relation has just been shown to hold over almost all of Argentina, from the subtropics to the subantarctic, from the Atlantic Coast to the Andes Mountains, in regions where the mean annual rainfall ranges from 80 mm to 1,250 mm and the annual number of days with rain from 30 to 150 days. *It is therefore plausible to suggest that equation (1) represents a general statistical law that is valid for most regions of the globe.* At this time it is not possible to prove this contention because of the labor involved, but reference is made to the rainfall of San Juan, Puerto Rico, (RIEHL, 1950) where a similar distribution prevails. The practical usefulness of the distribution law (1) for climatological and hydrological purposes — if proven generally valid — requires no elaboration.

Rainstorm analysis

It is of interest now to turn to some dynamical features of Argentine rainfall. The measurement of precipitation in 24-hourly amounts is a statistical device that does not give any information about the frequency of natural rainfall periods (rainstorms). Recently, RIEHL (1949) made an application of

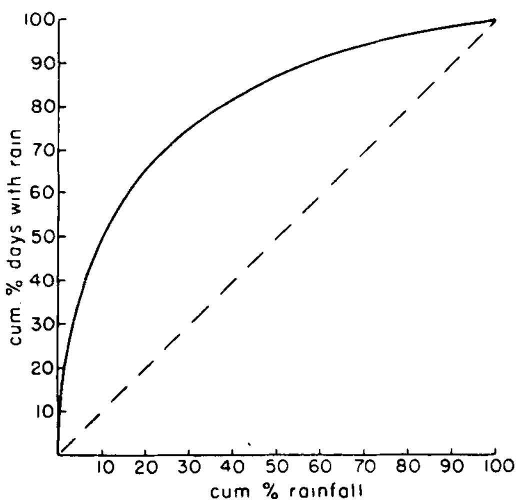

Fig. 4. Percent cumulative rainfall (abscissa) against percent cumulative number of days with rain (ordinate) for the annual precipitation of all zones combined.

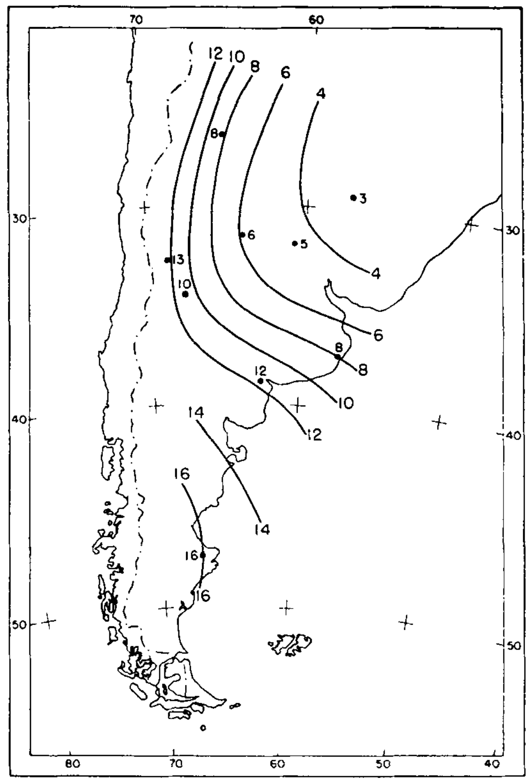

Fig. 5. The percentage of the mean annual rainfall that is not due to organized rainstorms.

the rainstorm concept developed in hydrometeorology to the rainfall of Hawaii. The following treatment for Argentina will follow the method used for Hawaii.

Rainfall can occur in organized form produced by general atmospheric disturbances, or in form of scattered local precipitation. It is reasonable to expect that during passage of a synoptic disturbance more than half of the stations located in a zone will report some precipitation. Therefore it will be assumed that a rainstorm has occurred when more than five stations of a zone record rainfall on a given day. The duration of a rainstorm is the number of consecutive days with precipitation measured at the majority of the stations.

Based on the foregoing definition, it is possible to calculate the rainfall due to rainstorms in each zone. The difference between this amount and total rainfall is the scattered local precipitation. Fig. 5 gives the percentage of annual rainfall that is derived from such local

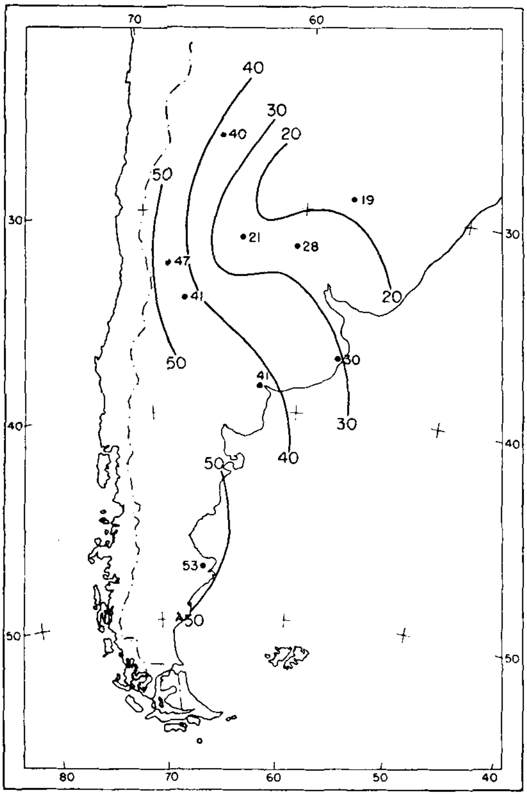

Fig. 6. The percentage of the annual number of days with rain that is due to days with unorganized precipitation.

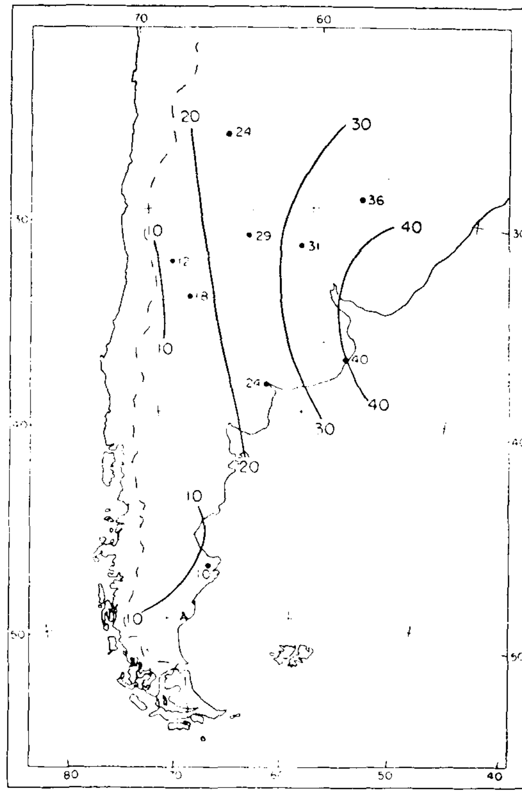

Fig. 7. Mean annual rainstorm frequency.

precipitation. The percentages are small everywhere and in no part of Argentina approach the amounts noted in Hawaii. Nevertheless, a pronounced gradient is evident, generally directed from the areas with high toward those with low annual rainfall. This situation corresponds to that found in Hawaii.

If we consider the percentage of the number of days with rain that is due to days with local precipitation (fig. 6), we encounter much larger numbers, again in correspondence to Hawaii. The gradient is the same as in case of fig. 5. The areas with lowest total rainfall have the highest frequency of scattered rain, which usually is the least effective form of precipitation for accumulation of soil moisture.

Fig. 7 shows the annual number of rainstorms, fig. 8 the annual number of rainstorm days and fig. 9 the average durations of rainstorms. It is seen that the storm frequency increases rapidly from the mountains toward the coast, but that the duration of the disturbances varies within relatively narrow limits, roughly from two to three days. Fig. 10 a shows the storm frequency as a function of longitude, therefore distance from the Andes Mountains, in cross-section form. Many of the provinces experience months without any rainstorms, especially in winter. The number of months without storms also is mainly dependent on proximity to the Andes (fig. 10 b).

We can now analyze the rainstorms in the same way as the daily precipitation and ask what percentage of the rainfall attributable to disturbances is accounted for by what percentage of the number of rainstorms. The result of the analysis (table 4) is quite analogous to that previously encountered in table 3. *There is a remarkable uniformity at both 50 % and 75 % levels of precipitation, and the mean deviations are only slightly larger than in case of the daily rainfall.* The southernmost zone (Sur) is not included in table 4 since, as stated

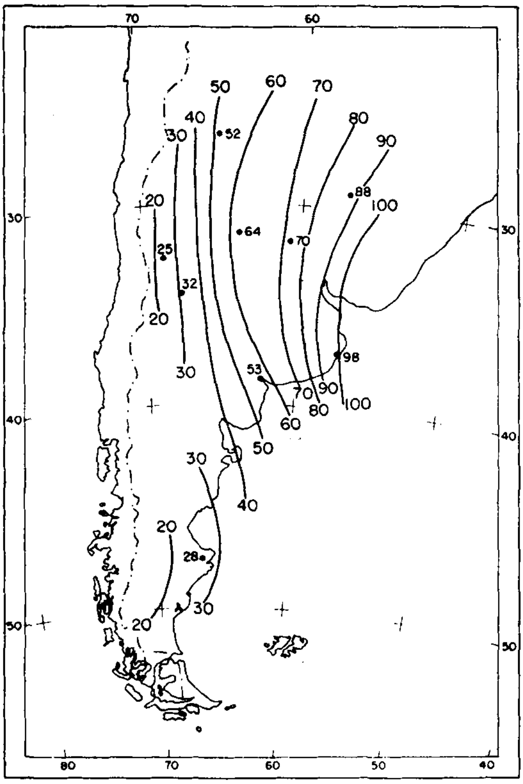

Fig. 8. Annual number of days with rain due to rainstorms.

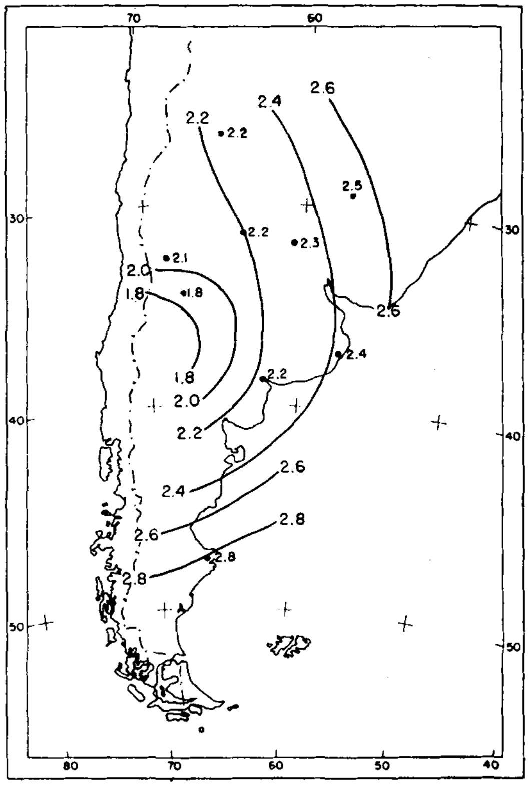

Fig. 9. Mean duration of rainstorms (days).

initially, it was not possible to form a group of 10 stations in that region. *Because of the great uniformity, both in space and time, it is again possible to combine all zones and construct a graph representative for all of Argentina* (fig. 11). The curve shown in this figure also can be approximated by the distribution law (1). In this case the constants have the values $a = 1.73 \cdot 10^{-1}$ and $b = 1.74 \cdot 10^{-2}$. *General validity of these constants over a major portion of the globe is again suggested.*

Within Argentina, we obtain a clear picture of the meaning of fig. 11 through comparison with figs. 7—8. Since the upper 50 % of the rainfall stem from slightly more than 20 % of the number of rainstorms, the region near the mouth of the Rio de la Plata will have about 20—25 days with appreciable rainfall in the annual average and the Andes foothills 5—6 days. The same 50 % of the precipitation fall on eight to ten occasions per year in the extreme east, but are concentrated in 2—3

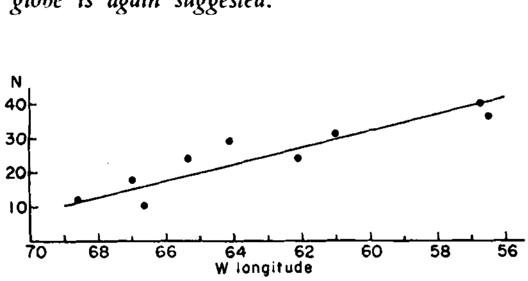

Fig. 10 a. East-west profile of annual rainstorm frequency.

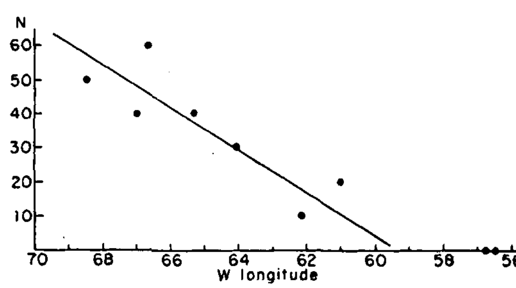

Fig. 10 b. East-west profile of the number of months per year that are without rainstorms.

Table 4. The percentages of the number of rainstorms that account for 50 % and 75 % of the annual precipitation due to rainstorms in each zone and in all zones combined. Mean deviation as indicated in Table 3. Months without any rainstorms (cf. fig. 10 b) are not included in the deviations.

Zone	50 % of total rainstorm precipitation		75 % of total rainstorm precipitation	
	Mean	Mean deviation	Mean	Mean deviation
Tucumán	25	3	48	4
Monte Caseros	22	3	43	6
Santa Fé	22	5	43	7
Córdoba	23	5	45	4
San Rafael	21	6	45	7
Mendoza	25	6	48	8
Mar del Plata	22	3	42	4
Bahia Blanca	23	4	45	3
Puerto Deseado	22	1	47	7
Mean for all zones	23	4	45	5

disturbances in the west. This is a precarious situation *that demonstrates clearly how small changes of the general circulation from year to year (small displacements of mean troughs and ridges aloft) can produce sharp fluctuations in the annual rainfall.* It has already been shown by Biel (for convenient reference, see Trewartha, 1943, p. 360) that a high annual variability actually exists. Biel's isolines of equal rainfall variability

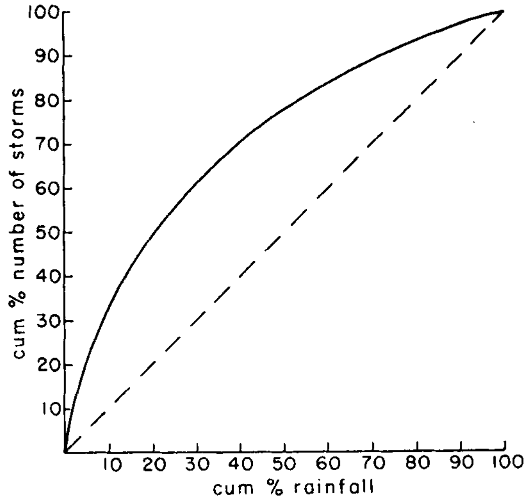

Fig. 11. Percent cumulative rainfall due to rainstorms (abscissa) against percent cumulative rainstorm frequency (ordinate) for the annual precipitation derived from rainstorms of all zones combined.

closely parallel the lines of annual storm frequency given in fig. 7.

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APPENDIX

List of stations used in the computation of the rainfall indices.

Tucumán: Bella Vista, Concepción, Famailla, Lules, Montero, Padilla, Pala Pala, Rio Colorado, Rio Seco, Tucumán.

Monte Caseros: Acuña, Baibiene, Bonpland, Curuzú Cuatiá, La Cruz, Libertad, Mercedes, Monte Caseros, Paso de los Libres, Tapebicua.

Santa Fé: Cañada Rosquin, Coronda, Esperanza, Galvez, Las Rosas, Pilar, Santa Fé, Totoras, Crespo, Paraná.

Córdoba: Alta Gracia, Córdoba, Cosquín, Jesús María, La Calera, La Cumbre, La Falda, Oncativo, Pilar, Villa Rosario.

San Rafael: Corral de Lorca, Cuadro Nacional, Gaspar Campos, Goico, Goudge, Media Luna, Monte Coman, Ovejeria, Pampa del Tigre, San Rafael.

Mendoza: Alto Verde, Buena Nueva, Luján de Cuyo Medrano, Mendoza, Palmira, Rivadavia, Santa Rosa Tres Porteñas, Ugarteche.

Mar del Plata: Ayacucho, Balcarce, Calfucura, Gral. Madariaga, Juancho, Las Armas, Maipú, Mar del Plata, Miramar, Vivoratá.

Bahia Blanca: Algarrobo, Argerich, Bahía Blanca, Buratovich, Fortín Mercedes, N. Levalle, Medanos, Montes de Oca, Ombucta, Pedro Luro.

Puerto Deseado: A. De Biedma, Cerro Blanco, Faro Cabo Blanco, Fitz Roy, Jaramillo, Pico Truncado, Puerto Deseado, Ramón Lista, Tehuelches, Tellier.

Sur: El Turbio, Faro Cabo Vírgenes, Rio Gallegos, Rio Grande, Ushuaia.