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Author(s): Joyce A. Quinn
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SEASONAL PRECIPITATION REGIONS AND ESTIMATION OF 30-YEAR MEANS FOR ARIZONA WEATHER STATIONS

Joyce A. Quinn
Department of Geography
California State University, Fresno
Fresno, CA 93740-0069

ABSTRACT

Seasonality of precipitation in Arizona is used to define regions for the purpose of estimating 1951-80 30-year mean monthly precipitation. Discriminant analysis is used to refine climatic zones in Arizona and to select the monthly precipitation variables that significantly distinguish six regions on the basis of seasonal precipitation. For each region, a series of regression equations are calculated, using 10-year means as independent variables and 30-year means as dependent variables. The equations provided can be used to estimate 1951-80 monthly precipitation means for weather stations that have a shorter term of record. Both the methodology and results are described.

Climatic data from National Weather Service (NWS) stations are often inadequate because of short or non-concurrent lengths of records. Both the World Meteorological Organization (Court 1967) and the NWS (1971) recommend the use of 30-year averages as "normals." Although many places do have continuous long-term records of 30 years or more, many remote weather stations have less. Changes in the NWS network since its beginning in the 19th century, *i.e.*, opening and closure of stations in different years, result in the problem that all stations necessary for climate-related research may not have the desired 30-year data base or concurrent records. Because there may be considerable annual variation in climate, particularly for precipitation in arid mountainous regions of Arizona, climatic records from different time periods are not comparable (Court 1967). A concurrent record using a 30-year normal is necessary in order to compare differences in climate across geographic areas of the state.

The techniques and simple formulas offered here are an alternative to methods that require complex formulas and extensive extrapolation of data over large geographic areas. There are several purposes to this paper. Discriminant analysis is described as a method for identifying seasonal precipitation regions in Arizona. The map and formulas generated from that analysis are presented and can be used to classify additional stations into the appropriate precipitation regions. A regression method is described by which 30-year precipitation means can be estimated from 10-year mean values. Regression equations for each month are provided for all six precipitation regions. One need only use the discriminant functions to classify a station needed for research into a region, then use the appropriate regression formulas to estimate 30-year precipition means.

Median values are the best measure of central tendency for precipitation, particularly in arid regions that exhibit large annual variation in rainfall (Slusser 1968), and when a record of sufficient length is available, the median is the preferred statistic. However, the mean has several advantages. It is readily available in climate records and is understood and used by non-climatologists. Most important, the mean has the mathematical properties that enable it to be used in advanced statistical analysis, while the median does not and therefore cannot be used in the same manner.

SEASONAL PRECIPITATION REGIONS

Before 30-year means can be estimated by the regression method described here, it must be reasonably certain that the stations used in such computations lie in homogenous precipitation zones. For this purpose, a map of seasonal precipitation regions in Arizona was created, using discriminant analysis (DA) as a method

of refining the boundaries between Sellers and Hill's (1974) topographic regions. DA is a multivariate technique which assumes *a priori* groupings of cases, and then classifies cases into those groups on the basis of the most important, or discriminating, variables (Kachigan 1986).

There have been many studies that use variations of factor analysis, eigenvectors, or principal components analysis (PCA) to produce maps of various climatic elements (Johnson 1980; Klugman 1978; Sellers 1968; Stidd 1967; Wright 1974). According to Kachigan (1986, p. 382), factor analysis "summarizes data and identifies relationships among variables." PCA, as a variation of factor analysis, recombines the variables as eigenvectors, providing data reduction, but mapping the results is an additional step. The coefficients, or importance, of each eigenvector at each station are manually plotted and isolines interpolated. One can create useful maps of trends or continua, but PCA does not lend itself to definition of borders or boundaries.

Discriminant analysis is "a procedure for identifying boundaries between groups of objects, the boundaries being defined in terms of those variable characteristics which distinguish or discriminate the objects in the respective criterion groups" (Kachigan 1986, p. 357). DA not only offers data reduction by selecting the combination of important variables, it also has the added advantage of placing cases, or stations, into groups which can be defined as geographical, or in this case, climatological regions. Because a major goal of this research was to delineate regions for further analysis, DA was the appropriate technique. DA also enables the user to classify new cases into the appropriate group through the use of discriminant functions, the formulas which weight the most important or discriminating variables. The discriminant functions presented in Table 3 require only monthly precipitation values and no complex statistical knowledge.

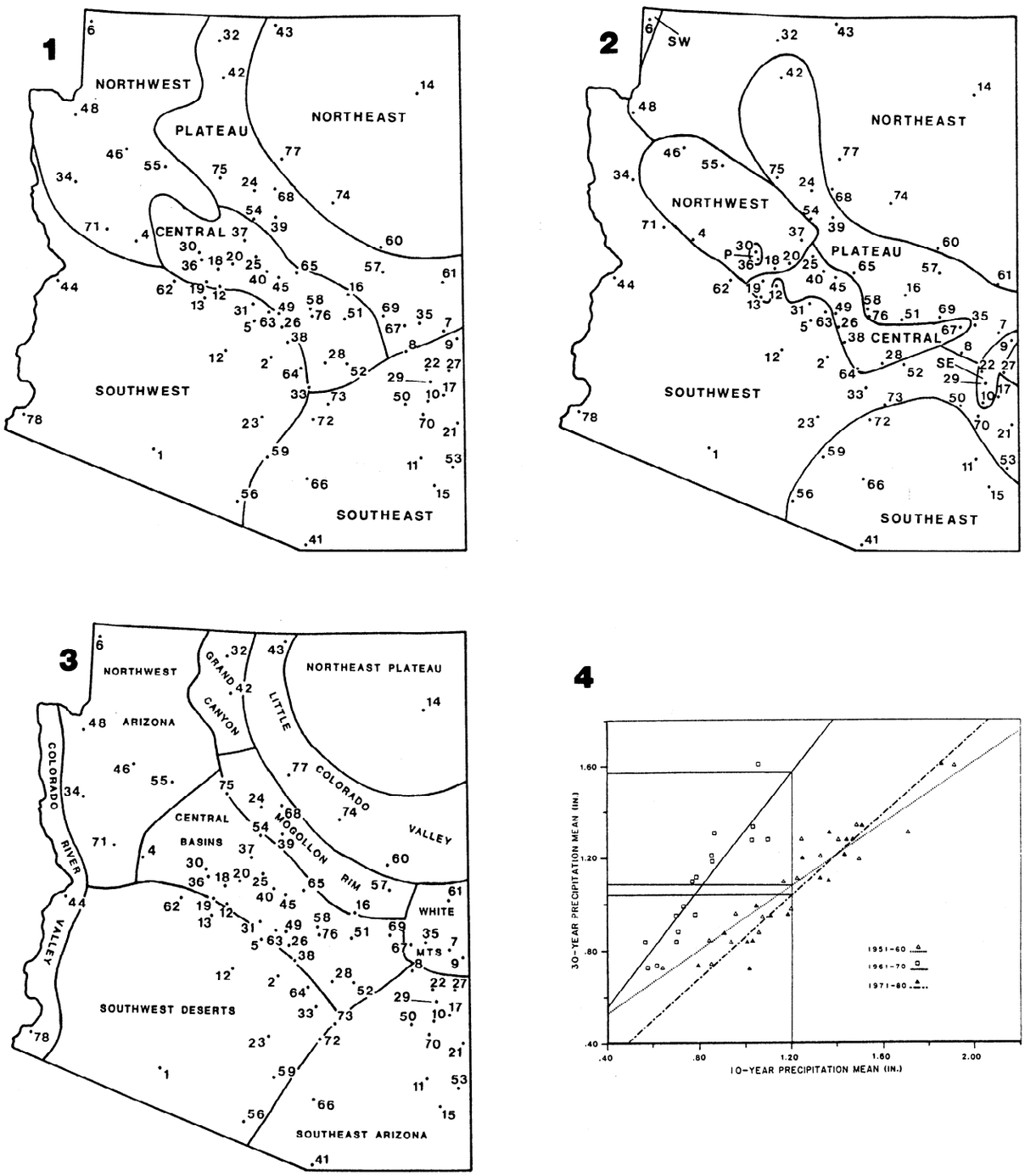
DATA

Mean monthly precipitation values for 251 NWS stations in Arizona were used as variables with which to distinguish seasonal precipitation regimes. Mean values represented a 30-year period where possible, 1931-60 or 1951-80, but some stations with shorter records (at least 10 years) were also used in order to include greater areal coverage. These two time periods were used together to increase the size of the data set and, thus, improve the accuracy of the DA; 1941-70 was not used because the other two 30-year periods each provided more stations. The use of non-concurrent time periods to define the regions is not believed to be a problem because DA looks at the relationship of variables to one another, *i.e.*, the relationship of each month's precipitation to the rest of the year, as well as at the magnitude of values. The purpose was to identify seasonal differences between regions, not precipitation totals. This concept is borne out by the fact that adjacent stations at different elevations with very different precipitation values were classified into the same region, reflecting the relationship of monthly precipitation values to each other and to the annual total -- the seasonality of precipitation. However, minor problems in regionalization, *i.e.*, a few stations that defy classification, may stem from non-concurrent records or inadequate length of record for some stations.

DISCRIMINANT ANALYSIS

DA is normally used to identify the combination of significant variables and create discriminant functions that can subsequently be used to classify unknown cases. The groups are permanently defined and are unchanged by the analysis. In this study, a major goal was to refine the groupings until they were most distinct according to the significant variables. The original topographic regions were not inviolate because they were not based on seasonality of precipitation; thus, they served only as an initial guide.

The initial groupings for the DA were Sellers & Hill's (1974) topographic regions, which are based on similarities of topography, vegetation, and climate characteristics (Figure 1). Variables were January through December monthly precipitation means; cases were weather stations. Prior to the first DA run, each station was coded into a topographic region based solely on its geographic location. Several discriminant analyses were then run using BMDP (Dixon & Brown 1981). Each DA selected the combination of variables, *i.e.*,



Figures 1-4. Figure 1. Topographic regions of Arizona according to Sellers and Hill (1974). Numbers on maps in Figs. 1-3 refer to NWS stations and are shown for locational purposes only. They do not represent the stations used in the DA or the regressions. Figure 2. Seasonal precipitation regions of Arizona. Figure 3. National Weather Service forecast zones (Durrenberger 1976). Figure 4. Regression of January's 10-year precipitation means against 30-year (1951-80) precipitation mean for the Southeast precipitation region.

monthly precipitation means, that best distinguished the regions. Boundary adjustments and region reassignments as indicated by the program results after each DA run were then made by the author. Whenever a station near the border of two regions was classified by DA into the adjacent region, the station was recoded to its new region according to DA, resulting in a boundary shift. After recoding, DA was run again, and further adjustments were made until the smallest number of misclassifications was achieved. Each adjustment altered the discriminant functions (equations), improved the distinctiveness of the regions, and increased the overall probability of correct classification, *i.e.*, the percent of stations that DA correctly classified into regions according to the significant precipitation variables. Incorrectly classified stations that were not near region boundaries could not be changed and must remain as anomalies in otherwise homogenous regions.

After the final alteration, over 91% ($p=.001$) of the 251 stations were correctly classified into six distinct regions, based on seasonal (or monthly) precipitation (Table 1, Figure 2). Most regions were well classified, with 84-100% of the sites correct. The Northwest region was most problematic; only 66.7% were correct, possibly due to abrupt variations in terrain or to few stations available for analysis. There are small enclaves of contrasting precipitation patterns within the Northwest, Southwest, and Plateau regions. The higher elevation areas around Groom Creek in the Northwest region classify solidly into the Plateau, and the Granville area straddling the Plateau and Southwest boundary has definite Southeast characteristics.

Table 1. Classification of stations into season precipitation region.

Region	n	% Correct
Northeast	32	100.0
Plateau	27	92.6
Central	19	84.2
Northwest	21	66.7
Southeast	64	92.2
Southwest	88	94.3
TOTAL	251	91.2

DA selected eight variables, shown in Table 2 with the mean values for each of the precipitation regions. It should be remembered that the effects of these months' precipitation must be considered simultaneously, as seasonal patterns, not individually. No one month by itself is effective in distinguishing these seasonal precipitation regions.

SEASONAL PRECIPITATION REGIONS

What follows is a brief description and explanation of the seasonal precipitation regimes in the six regions. These results corroborate Johnson's (1980) conclusions regarding the importance of summer precipitation in different areas of Arizona, but include more detail of precipitation patterns throughout the year. Precipitation in the Northeast region is fairly well distributed seasonally with a major increase in summer. The pattern in the Northwest is somewhat similar, although wetter, and with a biseasonal pattern of winter and summer maxima. The low values in spring are also in greater contrast to monthly precipitation

in the rest of the year. The Plateau region is also wet in every month except May; summer stands out as the wettest, with spring and fall only slightly drier than the rest of the year. Precipitation in the Central region is more evenly distributed between winter and summer. Spring and fall in the Central region receive less precipitation, and May is again the driest month. Wetter winters appear to distinguish the Central from the Northwest. The Southeast is readily distinguished by its greater summer precipitation, especially in contrast to the drier January. The Plateau is the only other region that has a comparatively high value for summer, but winter on the Plateau is also wet. The Southwest region has low values all year with only very slight maxima in winter and summer. A unifying factor in almost all regions is the tendency toward lower precipitation in spring and fall, and very low precipitation in May.

Table 2. Mean precipitation (in.) for months that significantly discriminate seasonal precipitation regions, by group.

	Northeast	Plateau	Central	Northwest	Southeast	Southwest
January	.82	2.05	2.17	1.35	1.13	.93
February	.73	1.66	2.05	1.30	.91	.73
April	.61	1.01	.93	.74	.38	.33
May	.47	.53	.35	.31	.17	.15
July	1.39	2.83	2.10	1.77	3.25	.98
October	.96	1.69	1.34	.92	.98	.67
November	.65	1.10	1.30	.77	.71	.55
December	.83	1.70	2.17	1.29	1.13	.82

Most of Arizona exhibits somewhat of a biseasonal precipitation regime with maxima both in winter and in summer (Bryson 1957; Sellers and Hill 1974). In winter the northern parts of the state receive precipitation from southward movement of low pressure troughs associated with the jet stream. In summer the Bermuda High expands and brings moist air to the state where it feeds summer afternoon thundershowers. The Southeast region has a summer maximum because that area is closest to the source of summer moisture; winter storms less frequently travel that far south. The Southwestern region has the least precipitation because it is most often dominated by the Pacific subtropical anticyclone, even in summer. The Northeast region is a drier area because its lower elevation is in the rainshadow of the Mogollon Rim and the Kaibab upwarp. The Plateau, Central, and Northwest regions receive a substantial portion of their precipitation from winter cyclonic storms traveling from the west, with the Plateau and Central regions being wetter due to their higher elevations. It should be mentioned that seasonality of precipitation in the northwestern part of the Northeast region is mainly extrapolation. There are very few weather stations in that remote area on which to base the classification.

The six seasonal precipitation regions delineated by the discriminant analysis of monthly precipitation (Figure 2) still retain a resemblance to the original regions described by Sellers and Hill (1974) (Figure 1). Two major changes in the regionalization presented here are the extension of the Southwest region east into the San Simon Valley and the extension of the Northeast region west to include most of the area north of the Grand Canyon. The San Simon Valley receives much less summer precipitation than does the Southeast region. The northwestern part of Arizona, as indicated by the few stations in that area, lacks the distinctly biseasonal precipitation pattern that the Northwest region exhibits. The area directly north of the Kaibab Plateau is lower in elevation and therefore receives less precipitation than does the Plateau region. Differences between the maps are to be expected since Sellers and Hill's regions are based on the "total" climate, not just the seasonality of precipitation.

A NWS map (Durrenberger 1976) divides the state into Forecast Zones and identifies areas with stations that have similar weather (Figure 3). These regions can be expected to have uniform weather conditions during a standard forecast period. There is some similarity between the NWS Forecast Zones and the seasonal precipitation regions (Southwest Deserts ≈ Southwest; Southeast Arizona ≈ Southeast; Northeast Plateau and Little Colorado Valley ≈ Northeast; Mogollon Rim and Grand Canyon ≈ Plateau). These Forecast Zones differ from the seasonal precipitation regions because elevation and terrain affect not only the precipitation received under a particular meteorological condition but also the temperatures and wind movement. The absolute precipitation values, as opposed to seasonal relationships, contribute to subdivisions according to elevations. These can be seen on the map as the relative lowlands of the Colorado River Valley and Little Colorado River Valley or the highlands of the White Mountains and Mogollon Rim. The NWS Central Basins Zone is subdivided by this analysis into the Central and Northwest seasonal precipitation regions, with the Northwest being drier. The NWS Northwest zone is admittedly one of varied topography and artificial boundaries (Durrenberger 1976), and the northern part may more appropriately belong to forecast regions north of the Grand Canyon.

Classifications are necessary in order to organize information, but it must be realized that no classification scheme can attempt to fulfill all needs. The seasonal precipitation classification system presented in Figure 2 serves the purpose of identifying homogeneous regions of precipitation seasonality for subsequent analysis.

DISCRIMINANT FUNCTIONS

In addition to the map of seasonal precipitation, a second useful result of this first step is the discriminant functions (Table 3). Discriminant functions are the formulas that use the selected monthly precipitation values (*i.e.*, the discriminating variables) to classify new stations (*i.e.*, cases) into the appropriate region or group. These formulas can be used to classify stations that have short-term records, less than the desired 1951-80 30-year period, into the appropriate seasonal precipitation region. This classification then determines whether the short-term stations can be considered consistent with their respective regions for the purpose of estimating 1951-80 precipitation means. Stations that do not classify correctly cannot be considered homogeneous with their geographic region, and their 1951-80 means cannot be estimated in the manner described below. It should be obvious that the target stations should not be part of the data set in the original analysis.

ESTIMATION OF 30-YEAR MEANS

The second step in estimation of 30-year precipitation means is regression (Coffin 1954). A series of regression equations for each of the six seasonal precipitation regions was used to estimate 1951-80 means of monthly precipitation for weather stations having a shorter period of record (Dixon and Brown 1981; Quattro 1987). With the exception of the Southwest region, all stations having complete 1951-80 data were used to calculate the regression equations for their respective regions. Because of their close proximity, especially in the Phoenix metropolitan area, some stations in the Southwest region were considered unnecessary duplication and were thus omitted from the analysis. The monthly means of a 10-year period were used as independent values against the 1951-80 monthly means as dependent values (Figure 4). The resulting equations make it possible to estimate 1951-80 means for stations that have only 10 years of record. The mean for the same 10-year period for any station within a seasonal precipitation region will have the same relationship with its respective 1951-80 mean. Three regression equations per month, one for each decade between 1951 and 1980 (1951-60, 1961-70, 1971-80) were calculated for each region, but regressions can be made for any 10-year (or longer) period according to the data available at the target station. Shorter time periods could also be used cautiously because probable errors in estimation might be larger.

Table 3. Discriminant functions for seasonal precipitation regions (for precipitation data in inches).

	Northeast	Plateau	Central	Northwest	Southeast	Southwest
January	-9.29	-6.14	-1.14	-4.93	-6.29	0.42
February	5.82	17.82	18.17	12.43	8.90	6.36
April	11.83	11.20	3.71	11.27	1.99	-1.68
May	25.47	16.15	-4.36	3.66	-5.80	0.69
July	1.40	2.78	1.34	2.43	7.94	0.44
October	17.01	25.51	9.48	9.41	6.10	7.07
November	-5.75	-14.38	-6.20	-6.54	1.23	-2.52
December	-6.26	-11.54	-3.90	-5.12	-4.67	-2.74
Constant	-14.34	-28.05	-19.72	-12.01	-15.91	-4.86

Multiply the station value for each variable by its coefficient and add the constant. Do calculations for each region, and classify the station into the region which produces the highest discriminant score.

e.g., -9.29(Jan) + 5.82(Feb) + 11.83(Apr) + 25.47(May) + 1.40(July) + 17.01(Oct) - 5.75(Nov) - 6.26(Dec) - 14.34 = discriminant score for Northeast region.

It is acknowledged that there is interdependence between the dependent and independent variables, *i.e.*, that the mean precipitation of each of the three decades is related to the mean value of the 30-year period. Although this is a violation of one of the basic assumptions of correlation and regression analysis, it is not believed to be a problem because the purpose here is to provide regression equations with which to estimate y values, not to "prove" the relationship between x and y.

The periods 1951-60, 1961-70, and 1971-80 are illustrated for January for the Southeast region in Figure 4. The decade 1961-70 was a dry 10-year period. Compare the 1.20 in mean for 1961-70 with almost 1.60 in for the 30-year period 1951-80. In contrast, 1951-60 and 1971-80 were wetter than the 30-year average. Compare 1.20 in for each of those decades with 1.08 and 1.04 in for 1951-80.

It is believed that regression of the 10-year mean against the 30-year mean will yield more accurate estimates of 30-year mean values than will the commonly used method of regression of values from an adjacent station because a series of mean values will more closely approximate a normal distribution (Lenhard and Baum 1954). Trial correlations between adjacent stations produced much larger standard errors of prediction, usually between .25 and 1.00 in, resulting in useless estimates. Regional regression of 10-year periods is also less tedious and time-consuming than is regression of year-by-year values of two adjacent weather stations. Furthermore, once the equations have been established for each seasonal precipitation region, it is a simple matter to estimate 1951-80 means by inserting the appropriate figures for any short-term station. Regression equations for the six regions are provided in Table 4. Because the purpose of the regressions is to provide the most accurate 1951-80 estimates, alternative equations are also given. In some instances the elimination of an anomalous outlier resulted in a tighter regression line and a lower standard error of prediction. All equations should be used cautiously as appropriate to the research situation. If the target short-term station is suspected to be similar to the excluded station, the original regression equation should be used in spite of the larger probable error.

Correlation coefficients of 10-year to 30-year regressions for the regions are quite high, r = .80 - .99, occasionally .60 - .70 for the drier, more variable months, and rarely .40 - .50. The standard error of prediction is also low, ranging from .02 to .43 in, but usually less than .15 in for the winter months, .10 in for dry May and June, and .30 in for July and August. The larger errors of prediction generally occur

Table 4. Regression equations by region (ERROR = standard error of prediction).

Southeast (n=18*)

	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	.269 + .677x	.08	.94	.052 + 1.273x	.10	.91	-.018 + .881x	.08	.94
Feb	.171 + .968x	.10	.87	.191 + .827x	.06	.95	-.027 + .804x	.07	.95
Mar	-.051 + .866x	.12	.92	.018 + 1.253x	.11	.93	.335 + .623x	.12	.91
Apr	-.020 + .700x	.05	.90	.079 + .967x	.06	.87	.089 + .925x	.04	.95
May	.084 + .541x	.04	.69	.088 + .672x	.05	.51	.078 + .389x	.03	.84
Jun	.227 + .458x	.10	.71	.276 + .582x	.10	.74	.178 + .599x	.10	.75
Jul	.646 + .822x	.38	.85	.837 + .768x	.21	.96	.831 + .786x	.32	.90
Aug	.848 + .648x	.19	.95	.211 + .877x	.25	.91	.789 + .988x	.33	.83
Sep	.307 + 1.540x	.20	.81	.248 + .593x	.12	.93	.268 + .767x	.13	.92
Oct	.418 + .673x	.11	.84	.557 + .957x	.15	.69	.139 + .557x	.09	.90
Nov	.050 + 1.143x	.09	.89	.092 + .793x	.05	.96	.072 + .818x	.05	.96
Dec	.166 + 1.550x	.13	.94	.085 + .582x	.08	.98	.219 + .977x	.17	.89
May	.034 + .764x (without Redington and Sasabe)	.03	.90	.002 + 1.400x (without Stephens Ranch and Chiricahua)	.03	.94	---		

* Apache Powder Co, Canelo 1 NW, Chiricahua Nat Mon, Douglas B D FAA AP, N Lazy H Ranch, Nogales, Patagonia, Pearce, Portal 4 SW, Redington, Ruby Star Ranch, Rucker Canyon, Santa Rita Exp Range, Sasabe 7 NW, Stephens Ranch, Tombstone, Tumacacori Nat Mon, Y-Lightning Ranch

Table 4. continued.

Northwest (n=10*)

	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	.043 + .901x	.08	.97	.251 + 1.089x	.08	.98	-.090 + .900x	.10	.96
Feb	.156 + 1.145x	.12	.94	-.020 + 1.276x	.21	.81	.258 + .549x	.10	.96
Mar	.313 + .974x	.07	.97	-.410 + 1.291x	.09	.96	.134 + .752x	.03	.99
Apr	.160 + 1.113x	.07	.90	.140 + .781x	.07	.92	.226 + .763x	.05	.95
May	.075 + .843x	.05	.90	.257 + .507x	.07	.72	.099 + .569x	.07	.75
Jun	.140 + .460x	.05	.86	.138 + .710x	.07	.74	.231 + .531x	.09	.51
Jul	.242 + .872x	.24	.94	.172 + .857x	.16	.97	.259 + .979x	.28	.92
Aug	.550 + .674x	.22	.93	.704 + .656x	.30	.87	.622 + 1.028x	.38	.78
Sep	.424 + .799x	.16	.64	.389 + .535x	.07	.94	.473 + .632x	.15	.72
Oct	0 + .994x	.09	.93	.198 + 1.336x	.15	.75	.216 + .566x	.02	.99
Nov	.008 + 1.171x	.12	.90	.153 + .745x	.06	.98	.092 + .876x	.09	.95
Dec	.440 + .941x	.13	.91	.219 + .580x	.10	.95	-.250 + 1.391x	.15	.88
May	---			.120 + .983x without Chino Valley	.07	.91	.026 + .661x without Jerome	.04	.97
Jun	---			---			.007 + 1.210x without Walnut Grove	.08	.87
Aug	---			---			.038 + 1.343x without Cordes and Peach Springs	.23	.98
Oct	---			.016 + 1.577x without Prescott	.10	.97	---		

* Chino Valley, Cordes, Jerome, Montezuma Castle N M, Peach Springs, Prescott, Seligman, Truxton Canyon, Walnut Creek, Walnut Grove

Table 4. continued.

Central (n=9*)	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	-.120 + .940x	.16	.94	-.020 + 1.407x	.13	.96	.520 + .661x	.12	.97
Feb	.313 + 1.144x	.17	.95	-.080 + 1.388x	.24	.91	.182 + .591x	.11	.98
Mar	.230 + 1.022x	.27	.76	.797 + .698x	.17	.91	.232 + .723x	.12	.95
Apr	-.090 + 1.020x	.12	.85	.383 + .628x	.10	.92	.208 + .763x	.12	.86
May	.126 + .786x	.08	.83	.227 + .772x	.07	.85	.011 + .670x	.06	.89
Jun	-.040 + .743x	.05	.87	.255 + .570x	.03	.97	.278 + .372x	.10	.34
Jul	.344 + .735x	.18	.97	.483 + .751x	.24	.94	.178 + 1.149x	.43	.79
Aug	.718 + .632x	.20	.97	-.050 + .916x	.21	.97	.076 + 1.417x	.42	.85
Sep	.948 + .496x	.19	.56	.581 + .455x	.10	.91	1.097 + .268x	.21	.38
Oct	.718 + .466x	.11	.81	.674 + 1.025x	.09	.89	.729 + .365x	.16	.55
Nov	.405 + .857x	.12	.86	.406 + .610x	.07	.96	.278 + .823x	.17	.71
Dec	.397 + 1.192x	.24	.85	.478 + .522x	.11	.97	-.610 + 1.553x	.16	.94
without Crown King									
Feb	---			.081 + 1.238x	.21	.95	---		
Mar	.133 + 1.034x	.20	.96	---			---		
Jul	---			---			.177 + 1.079x	.28	.95
Aug	---			---			.188 + 1.312x	.34	.95
Oct	---			---			.023 + .700x	.16	.96
Nov	---			---			.063 + .958x	.17	.94
Dec	---			---			.015 + 1.179x	.13	.98

* Camp Wood, Childs, Crown King, Gisela, Irving, Miami, Payson, Roosevelt 1 WNW, Superior

Table 4. continued.

Northeast (n=13*)

	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	.049 + .857x	.07	.98	.114 + 1.103x	.08	.98	-.110 + 1.003x	.09	.97
Feb	-.030 + 1.316x	.07	.97	.067 + 1.163x	.12	.91	-.050 + .765x	.07	.97
Mar	-.150 + 1.528x	.12	.95	.109 + .802x	.07	.98	-.080 + .987x	.10	.97
Apr	-.180 + 1.164x	.09	.88	.161 + .709x	.04	.98	-.060 + 1.293x	.08	.92
May	.150 + .688x	.10	.68	.155 + .771x	.10	.68	.135 + .538x	.06	.89
Jun	.184 + .377x	.06	.64	.199 + .608x	.06	.75	.220 + .512x	.07	.59
Jul	.210 + .797x	.20	.93	.355 + .751x	.17	.95	.040 + 1.053x	.23	.91
Aug	.416 + .683x	.35	.84	.064 + .825x	.32	.87	.704 + .775x	.23	.93
Sep	.446 + .757x	.21	.63	.323 + .578x	.11	.92	.210 + .754x	.16	.82
Oct	.258 + .778x	.15	.78	.441 + .789x	.12	.86	.385 + .489x	.15	.79
Nov	.105 + 1.030x	.13	.88	.071 + .877x	.10	.93	.009 + .843x	.09	.94
Dec	.045 + 1.269x	.29	.74	.050 + .733x	.08	.98	.048 + .972x	.09	.98
Feb	---			.218 + .754x	.07	.87	---		
				without Walnut Canyon					
Aug	-.160 + 1.031x	.17	.96	-.140 + .959x	.24	.96			
	without Walnut Canyon			without Window Rock					
Oct	---			.442 + .750x	.06	.96	---		
				without Walnut Canyon					
Dec	.242 + .777x	.14	.79	---			---		
	without Walnut Canyon								

* Betatakin, Ganado, Holbrook, Lees Ferry, Leupp, Petrified Forest NP, Saint Johns, Snowflake, Springerville, Walnut Canyon

Table 4. continued.

Plateau (n=12*)

	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	-.150 + .939x	.09	.99	.017 + 1.326x	.23	.97	.274 + .782x	.16	.99
Feb	-.070 + 1.197x	.10	.99	.029 + 1.284x	.15	.98	.094 + .692x	.07	.99
Mar	-.400 + 1.241x	.31	.94	.388 + .916x	.27	.95	.312 + .736x	.18	.98
Apr	-.180 + .989x	.10	.98	.262 + .820x	.11	.98	-.010 + 1.128x	.09	.98
May	.130 + .917x	.09	.92	.252 + .903x	.10	.91	.028 + .663x	.11	.88
Jun	.248 + .451x	.10	.70	.123 + 1.124x	.06	.89	.364 + .419x	.10	.71
Jul	.524 + .846x	.20	.91	.838 + .695x	.21	.90	.592 + .840x	.25	.86
Aug	.437 + .752x	.19	.95	.606 + .773x	.25	.90	1.896 + .563x	.44	.66
Sep	1.263 + .396x	.30	.43	.529 + .547x	.12	.94	.899 + .535x	.24	.71
Oct	.349 + .817x	.12	.95	.777 + .886x	.22	.81	.315 + .619x	.21	.84
Nov	.256 + 1.000x	.16	.96	.202 + .755x	.14	.96	.069 + .931x	.24	.89
Dec	.117 + 1.256x	.19	.97	.034 + .675x	.14	.98	.199 + 1.145x	.21	.96
Sep	.967 + .677x without Fort Valley and Chevelon RS	.24	.71	---			---		

* Alpine, Black River Pumps, Chevelon R S, Fort Valley, Fritz Ranch, Heber R S, Junipine, McNary, Pinetop Fish Htchy, Whiteriver, Williams, Tonto Creek Fish Htchy

Table 4. continued.

Southwest (n=30*)

	1951-80	ERROR	r	1961-70	ERROR	r	1971-80	ERROR	r
Jan	.103 + .792x	.10	.97	.012 + 1.343x	.12	.95	.098 + .814x	.12	.96
Feb	-.010 + 1.385x	.14	.91	.008 + 1.055x	.13	.92	.187 + .579x	.09	.97
Mar	.166 + .909x	.19	.90	-.001 + 1.135x	.09	.98	.125 + .727x	.12	.96
Apr	.024 + .763x	.07	.91	.025 + 1.107x	.08	.88	.074 + .846x	.03	.98
May	.044 + .780x	.04	.87	.048 + 1.197x	.05	.77	.031 + .519x	.03	.91
Jun	.028 + .702x	.05	.91	.083 + .650x	.08	.64	.062 + .610x	.06	.84
Jul	.030 + .826x	.22	.91	.259 + .823x	.20	.93	.287 + .891x	.20	.92
Aug	.259 + .708x	.26	.89	.344 + .695x	.16	.96	.320 + 1.101x	.29	.86
Sep	.301 + 1.149x	.19	.80	.038 + .660x	.12	.93	.202 + .746x	.13	.91
Oct	.106 + .811x	.11	.95	.156 + 1.529x	.21	.77	.063 + .671x	.11	.95
Nov	.170 + 1.024x	.12	.89	.038 + .788x	.09	.94	.063 + .849x	.06	.97
Dec	.099 + 1.417x	.13	.95	.056 + .631x	.11	.96	.031 + 1.139x	.11	.96
Jan	---			---			.053 + .841x	.09	.98
							without Granite Reef Dam		
Apr	---			.037 + 1.032x	.07	.91	---		
				without Superior					
Jul	.012 + .757x	.13	.97	---			---		
	without Clifton & Duncan								
Aug	.082 + .821x	.23	.93	---			.196 + 1.178x	.23	.93
	without Horseshoe Dam						without Horseshoe Dam		
Nov	.092 + 1.151x	.10	.94	---			---		
	without Chandler Heights								

* Ajo, Bartlett Dam, Buckeye, Casa Grande, Chandler, Chandler Heights, Clifton, Deer Valley, Duncan, Florence, Gila Bend, Granite Reef Dam, Griggs 3 W, Horseshoe Dam, Kelvin, Kingman No 2, Laveen 3 SSE, Litchfield Park, Organ Pipe Nat Mon, Parker, Sacaton, Safford Exp Farm, San Carlos Res, Superior, Tempe, Tolleson 1 E p73, Wellton, Wickenburg, Winkelman 6 S, Yuma WSO

in months that receive more precipitation. For a few months, the regression is poor and error is high due to extreme variability of thunderstorm precipitation in desert regions. A test of the quality of the prediction was made by eliminating one station from each of the regions at random, rerunning the regression, and estimating the 1951-80 mean for the eliminated station (Table 5). Predicted values compare well with actual precipitation means.

It is acknowledged that there may be error in the estimate of 1951-80 monthly precipitation means. However, a carefully estimated value is often the alternative to no data at all.

Table 5. Comparison of selected actual 1951-80 precipitation means (in.) with values predicted by regression equations, by seasonal precipitation regions.

Region & Site	Month & Year	Actual 1951-80 X	Predicted 1951-80 X	Standard Error of Prediction
Southeast				
Canelo	July 1951-60	4.38	4.73	.38
Central				
Irving	June 1951-60	.50	.56	.05
Plateau				
Alpine	March 1961-70	1.14	1.11	.29
Northwest				
Chino Valley	January 1971-80	1.02	1.02	.10
Northeast				
Leupp	November 1971-80	.31	.30	.09
Southwest				
Ajo	August 1961-70	2.24	2.15	.17

Table 6. NWS stations shown on Figures 1, 2, and 3.

1. Ajo
2. Apache Junction
3. Ash Fork
4. Bagdad 2 E
5. Bartlett Dam
6. Beaver Dam
7. Beaverhead Lodge
8. Black River Pumps
9. Blue
10. Bonita Creek 2
11. Bowie
12. Bumble Bee
13. Castle Hot Springs Hotel
14. Chinle
15. Chiricahua Nat Mon
16. Cibecue
17. Clifton
18. Cordes
19. Crown King
20. Dugas 2 SE
21. Duncan
22. Eagle Creek
23. Eloy
24. Flagstaff WB Airport
25. Fossil Springs
26. Four Peaks
27. Fritz Ranch
28. Globe
29. Granville
30. Groom Creek
31. Horseshoe Dam
32. Jacob Lake
33. Kelvin
34. Kingman No 2
35. Maverick
36. Mingus Mtn Lookout
37. Montezuma Castle Nat Mon
38. Mormon Flat
39. Mormon Lake Ranger Sta
40. Natural Bridge
41. Nogales
42. North Rim Checking Sta
43. Page
44. Parker
45. Payson
46. Peach Springs
47. Phoenix WB Airport
48. Pierce Ferry 17 SSW
49. Reno Ranger Sta
50. Safford
51. Salt River
52. San Carlos
53. San Simon 9 ESE
54. Sedona Ranger Sta
55. Seligman
56. Sells
57. Show Low City
58. Sierra Ancha
59. Silver Bell
60. Snowflake
61. Springerville
62. Stanton
63. Sunflower 3 NNW
64. Superior
65. Tonto Creek Fish Htchy
66. Tucson WB Airport
67. Turkey Creek
68. Walnut Canyon Nat Mon
69. Whiteriver
70. Whitlock Valley R2 on W1
71. Wickieup
72. Willow Springs Ranch
73. Winkelman 6 S
74. Winslow WB Airport
75. Williams
76. Workman Creek
77. Wupatki Nat Mon
78. Yuma

APPLICATIONS

The primary purpose for this study was to provide a simple way to obtain estimates of 30-year precipitation means. By using the discriminant functions in Table 3, one can classify the station for which precipitation estimates are needed into the appropriate seasonal precipitation region. Then, by using the 10-year formulas for that region in Table 4, estimates of the 30-year monthly means can be calculated.

The seasonal precipitation regions and the associated discriminant functions can also be used as an indicator of climatic change or fluctuation. The map in Figure 2 can be used as a baseline against which to "test" climatic change, at least in terms of seasonal precipitation. A DA run using a particular time period may produce different boundary lines between regions, indicating short-term climatic fluctuations.

SUMMARY

A map of seasonal precipitation regions of Arizona was produced by using mean monthly precipitation as variables in discriminant analysis. The groups from an existing regional map of Arizona were refined by classifying 251 weather stations into seasonal precipitation regions. This system can then be used to classify stations of unknown affinity into their respective regions. Using this regionalization as a base, 1951-80 monthly precipitation means were estimated by a series of regression equations. Data from 10-year periods were used as independent variables against 30-year data as dependent variables. In this manner, 30-year data can be estimated for stations with short lengths of record.

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