JP1.6 PRINCIPAL COMPONENT ANALYSIS OF MONTH-TO-MONTH PRECIPITATION VARIABILITY FOR NCDC CALIFORNIA CLIMATIC DIVISIONS, (1895-6 THROUGH 2000-1 SEASONS)

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1. INTRODUCTION

The purpose of the following study is to investigate the existence, nature, and prominence of month-to-month patterns or modes in precipitation variability over the July-June rain year for the seven NCDC California climatic divisions. Period of record is the 1895-96 through 2000-2001 seasons. The analysis makes use of statistically transformed (and in some cases combined and transformed) monthly precipitation data, principal components analysis, varimax rotation, and time-series plots. In addition, the single-most anomalous yearly patterns are identified for each division by utilizing the concept of multivariate statistical distances. The analysis assumes reasonably consistent areal averaging methods over the 106-year history. Figure 1 below is a map of the NCDC California climate divisions.

Figure 1. NCDC California Climate Divisions

2. METHODS AND PROCEDURES

Much of the theory that supports the use of Principal Component Analysis assumes multivariate normal data. Monthly precipitation data in raw form are notoriously non-normal, frequently exhibiting positive skewness and/or “trace” or zero observations on the bounded left side. To allow the use of measurable and non-measurable data alike and to bring them into approximate univariate-normal conformance, the Box-Cox power transformation procedure (Johnson and Wichern, 1982) was applied to the individual monthly series, preceded by addition of an .01 constant or “start” (Mosteller and Tukey, 1977) to those that had at least one zero observation (no ‘trace’ recordings appear in the divisional data). Results were assessed by inspection of normal probability plots. Power transformations on combined July to November and April to June categories ultimately had to be adapted because for some divisions, particularly the most southerly ones, individual-month conformance to normality was poor even after Box-Cox transformation, attributable to a large number of very dry or rainless months. The problem affected fewer months in the more northerly divisions, but for consistency, the July-November and April-June groupings were used for all seven. The transformed series were also standardized. Thus, the monthly series were analyzed in terms of power transformed relative anomalies (z-scores) in place of absolute magnitudes.

Interpreted, a given transformed distribution’s z-score represented a relative deviation, approximately, from its parent distribution’s median. To explain, in the 42 individual California series (seven climatic divisions and six periods per division), parent-series precipitation magnitudes corresponding to zero z-scores in their transformed distributions typically ranged between 5% lower or higher than their actual medians, but were always at least 16% lower than their means. Grand average of the 42 “magnitudes” was equal to the average of the 42 medians (3.40”).

With the precipitation data transformed and standardized, the PCA was next performed, division-by-division. Eigenvalue magnitudes of greater than to just under 1.0 were used as a cutoff criterion, resulting in retention of three components for each division. To sharpen eigenvector coefficient contrasts in these three, a varimax rotation was then performed. As a tradeoff for this eigenvector coefficient contrast enhancement, eigenvalue magnitude contrasts became slightly less than before. First component eigenvalues were now slightly reduced, but third component magnitudes for all divisions were now at least 1.0, or that of a full-fledged original variable.

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3. RESULTS

3.1 – Division 6 and 7 Modes

Starting with the most southerly divisions, Tables 1 and 2 display summary statistics for Divisions 6 ("South Coast Drainage") and 7 ("Southeast Desert Basins"), respectively. Primary mode for Division 6 (Table 1) contrasts comparatively high eigenvector coefficients for January, February, and March (+.447, +.477, and +.507, respectively) with relatively slight values for July-November, December, and April-June (-0.147, +0.181, and -0.029, respectively). Rotated loadings for January, February, and March (+.587, +.658, and +.701, respectively) are also much higher than the rule-of-thumb 0.300 absolute value for factor retention. The secondary mode contrasts large eigenvector coefficients for the July-November and December periods (+.566 and +.727, respectively) with undistinguished magnitudes for the other four. Mode three contrasts an overwhelmingly high coefficient for April-June (+.997) with those of the other periods. Altogether the three components explain a modest 58.3% of the variance.

Division 7's pattern of statistics is strikingly similar to Division 6's. Primary component contrasts comparatively high eigenvector coefficients for January, February, and March (+.416, +.454, and +.539, respectively) with comparatively low values for the other three. Rotated loadings are similarly high for January, February, and March (+.585, +.651, and +.762, respectively). Mode two contrasts high eigenvector coefficients for the July-November and December periods (+.653 and +.655, respectively) with very low magnitudes for the others. The third mode also exhibits the exceptionally high coefficient for April-June (+.988). In total, the three components account for 59.7% of the variance. Mode-by-mode correlations of scores between Divisions 6 and 7, are +.980, +.895, and +.916, respectively.

3.2 – Division 4 and 5 Modes

Moving north, Tables 3 and 4 display summary statistics for Divisions 4 ("Central Coast Drainage") and 5 ("San Joaquin Drainage"), respectively. For these, the three modes explain 59.9% and 59.7% percent of the total variance, respectively. Although the period-by-period comparisons are not exact, Division 4's and 5's primary modes resemble 6's and 7's secondary modes; and 4's and 5's secondary modes resemble 6's and 7's primary modes. For example, Division 4's primary component contrasts comparatively high eigenvector coefficients for December and January (+.570 and +.559, respectively) along with April-June (+.329) with slight values for the others. Allowing for the one-period offset, the contiguous two-period December and January selection is not unlike the July to November and December secondary mode pair for divisions 6 and 7; also, December is common to each. Division 5's primary mode configuration is quite similar to Division

Table 1 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #6 -"South Coast Drainage"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.259	**+0.654**	+0.012
DEC	+0.171	**+0.801**	+0.022
JAN	**+0.587**	+0.166	-0.031
FEB	**+0.658**	-0.141	-0.006
MAR	**+0.701**	-0.107	+0.086
APJU	+0.029	+0.031	**+0.996**
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.365	1.128	1.001
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	22.754	41.660	58.346
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.147	**+0.566**	-0.002
DEC	+0.181	**+0.727**	-0.021
JAN	**+0.447**	+0.190	-0.069
FEB	**+0.477**	-0.080	-0.035
MAR	**+0.507**	-0.051	+0.054
APJU	-0.029	-0.013	**+0.997**

Table 2 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #7 – "Southeast Desert Basins"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.200	**+0.760**	+0.005
DEC	+0.181	**+0.757**	-0.039
JAN	**+0.585**	-0.022	-0.057
FEB	**+0.651**	+0.071	+0.147
MAR	**+0.762**	-0.062	-0.014
APJU	+0.036	-0.034	**+0.988**
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.420	1.161	1.003
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	23.675	43.025	59.737
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.130	**+0.653**	-0.058
DEC	+0.142	**+0.655**	-0.020
JAN	**+0.416**	-0.012	-0.090
FEB	**+0.454**	+0.077	+0.114
MAR	**+0.539**	-0.042	-0.058
APJU	-0.030	+0.010	**+0.988**

4's, with relatively high eigenvector coefficients for December and January (+.672 and +.525, respectively), and April-June (+.206). The above-cited periods for Divisions 4 and 5 are associated with rotated loadings' absolute values of 0.30 or higher, the loadings magnitudes and corresponding eigenvector coefficients, following the convention used in Tables 1 through 7, appearing in bold-faced type. Repeating this loadings rule-of-thumb, secondary mode for Division 4 covers four successive periods, December, January, February, and March; identical to that of the two southern divisions' primary mode, save for December. Eigenvector coefficients are highest for February and March (+0.500 and +0.631, respectively), conforming to that of the southern divisions' primary mode. Division 5's secondary mode is very similar to Division 4's, except that December, using the loadings' criterion, is excluded, the remaining selection thus matching the southern divisions' primary (January, February, and March). Division 5's secondary mode eigenvalue magnitude (1.227) is barely lower than its primary mode's (1.230). Except for similarly high, positive loadings and eigenvector coefficients for July-November, third mode PCA properties for Division 4 and 5 differ in sign and magnitude to a considerable extent, especially for the February and April-June periods. Correlation of scores between Divisions 4 and 5, in order of mode, are +.916, +.886, and +.149, respectively. Average correlation of scores for the Division 4 and 5 secondary modes with those generated for the Division 6 and 7 primary modes is +.730. That for the Division 4 and 5 primaries versus the 6 and 7 secondaries is +.347. Average correlations for the 4 and 5 primaries versus the 6 and 7 primaries is +.332.

3.3 Division 1, 2, and 3 Modes

Tables 5, 6, and 7 list summary statistics for the northern Divisions 1, 2 and 3 ("North Coast Drainage", Sacramento Drainage", and "Northeast Interior Basin", respectively). Coefficient configurations are much alike for all three modes, and similar also to the first two for Divisions 4 and 5. Percents of total variance explained are 61.3%, 60,6%, and 60.2%, respectively. Primary mode for divisions 1, 2, and 3 exhibits highly positive eigenvector coefficient signs for December, January and April-June, the latter period magnitudes more enhanced compared to those for Divisions 4 and 5. Mode two contrasts relatively negative coefficient signs for December with highly positive ones for February and March. This compares favorably with the coefficient configurations in Divisions 4 and 5, except that January for Divisions 1, 2, and 3 is relatively insignificant in loadings magnitude (+.094, +.193, and +.184, respectively), falling short of the arbitrary 0.300 cutoff criterion. The December Division 3 loading (-.251) also falls just short in this regard. Mode 3 in all three divisions contrasts significantly positive eigenvector coefficients for July-November and December (average magnitudes: +.855 and +.369, respectively) with relatively insignificant values for the other four

Table 3 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #4 – "Central Coast Drainage"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.027	-0.033	**+0.834**
DEC	**+0.718**	**-0.390**	+0.027
JAN	**+0.732**	**+0.309**	-0.068
FEB	+0.146	**+0.610**	**-0.319**
MAR	-0.048	**+0.750**	+0.247
APJU	**+0.482**	+0.129	**+0.470**
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.307	1.201	1.085
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	21.778	41.791	59.875
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.088	-0.018	**+0.778**
DEC	**+0.570**	**-0.355**	-0.038
JAN	**+0.559**	**+0.227**	-0.120
FEB	+0.114	**+0.500**	**-0.303**
MAR	-0.088	**+0.631**	+0.242
APJU	**+0.329**	+0.093	**+0.399**

Table 4 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #5 – "San Joaquin Drainage"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	+0.165	-0.143	**+0.735**
DEC	**+0.803**	-0.199	+0.106
JAN	**+0.663**	**+0.348**	-0.221
FEB	+0.064	**+0.784**	+0.180
MAR	-0.070	**+0.644**	-0.205
APJU	**+0.332**	-0.132	**-0.672**
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.230	1.227	1.126
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	20.508	40.961	59.726
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.209	-0.060	**+0.673**
DEC	**+0.672**	-0.153	+0.162
JAN	**+0.525**	**+0.270**	-0.107
FEB	+0.073	**+0.658**	+0.230
MAR	-0.076	**+0.513**	-0.143
APJU	**+0.206**	-0.159	**-0.586**

Table 5 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #1 – "North Coast Drainage"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.062	+0.119	**+0.889**
DEC	**+0.531**	**-0.317**	**+0.477**
JAN	**+0.763**	+0.094	+0.088
FEB	+0.177	**+0.747**	-0.123
MAR	-0.124	**+0.714**	+0.199
APJU	**+0.686**	+0.011	-0.142
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.386	1.191	1.100
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	23.096	42.942	61.279
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.113	+0.087	**+0.819**
DEC	**+0.339**	**-0.255**	**+0.399**
JAN	**+0.553**	+0.103	+0.018
FEB	+0.164	**+0.636**	-0.136
MAR	-0.083	**+0.594**	+0.184
APJU	**+0.513**	+0.034	-0.186

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Table 6 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #2 – "Sacramento Drainage"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.057	+0.083	**+0.917**
DEC	**+0.523**	**-0.329**	**+0.445**
JAN	**+0.779**	+0.193	-0.041
FEB	+0.112	**+0.663**	-0.130
MAR	-0.048	**+0.735**	+0.175
APJU	**+0.718**	-0.025	-0.023
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.415	1.133	1.088
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	23.578	42.468	60.608
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.106	+0.100	**+0.856**
DEC	**+0.340**	**-0.277**	**+0.366**
JAN	**+0.558**	+0.170	-0.088
FEB	+0.090	**+0.582**	-0.110
MAR	-0.046	**+0.654**	+0.186
APJU	**+0.513**	-0.022	-0.073

Table 7 - Statistics for First Three Components of Transformed Precipitation Anomalies - California Division #3 – "Northeast Interior Basins"

ROTATED LOADINGS			
PERIOD	#1	#2	#3
JLNV	-0.061	+0.104	**+0.937**
DEC	**+0.613**	-0.251	**+0.364**
JAN	**+0.751**	+0.184	-0.192
FEB	-0.085	**+0.723**	-0.001
MAR	+0.060	**+0.712**	+0.063
APJU	**+0.684**	-0.054	-0.016
EIGENVALUES			
MODE	#1	#2	#3
VALUE	1.423	1.140	1.052
CUMULATIVE PCT VARIANCE			
MODE	#1	#2	#3
VALUE	23.716	42.717	60.249
EIGENVECTOR COEFFICIENTS			
PERIOD	#1	#2	#3
JLNV	-0.048	+0.076	**+0.890**
DEC	**+0.417**	-0.196	**+0.343**
JAN	**+0.541**	+0.200	-0.193
FEB	-0.025	**+0.633**	-0.010
MAR	+0.076	**+0.629**	+0.050
APJU	**+0.480**	-0.014	-0.022

periods. Except for the highly positive July-November coefficients, the northern divisions' third mode configurations differ significantly from those of Divisions 4 and 5. Correlation of scores between Divisions 1 and 2, in order of mode, are +.955, +.942, and +.938 respectively. For Divisions 1 vs. 3 the sequence is +.821, .879, and .768; for 2 versus 3 it is +.861, +.920, and +.871.

In summary, there was much similarity in inter-monthly variability patterns between divisions of the same general latitude (e.g., 6 and 7, 4 and 5; and 1, 2, and 3), especially for the first two modes. The centrally situated 4 and 5 divisions were more similar to the northernmost 1, 2, and 3 divisions then they were to 6 and 7. Primary mode for 6 and 7 (significant coefficients for January, February, and March) was expressed in somewhat modified but still recognizable form as the secondary mode for 4 and 5; and 1, 2, and 3 (February and March retaining significantly positive coefficients in all cases). Allowing for the one-period offset, primary mode for the central and northern groups (highly positive coefficients for the two contiguous periods December and January) resembled that of the southern divisions' secondary (high coefficients for the two contiguous sequences' July-November and December). The relative distinctiveness of Division 6's and 7's patterns might relate to their greater proximity to the subtropical jet stream during winter, and the more southwesterly facing orientations of Division 6's Pacific coastline and mountain ranges (orographic influences on moist southwesterly flow).

3.4 First Component Scores' Time Series

With the principal eigenvector functions identified for the seven climate divisions, time series plots of the primary mode standardized scores were next constructed. Since it was already established that first component scores from similar latitude bands (i.e., the southern, central, and northern divisional designations) were highly correlated, to avoid redundancies, Division 6 was selected to represent the southern division, Division 4 the central, and Division 1 the northern. The NCEP Climate Prediction Center's online list of "Previous ENSO Events (1877-present)" was also utilized to relate the patterns in a general way to warm, cold, and neutral episodes.

Figures 2 through 4 are time series plots of the primary mode (first component) scores for Division 6, 4, and 1, respectively.

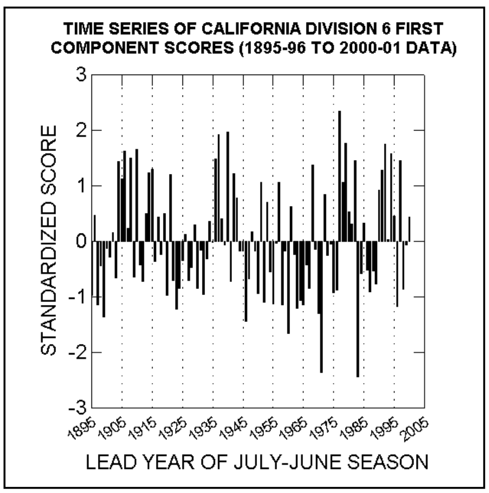

Figure 2. Time Series Plot of California Division 6 ("South Coast Drainage") First Component Scores for 1895-96 to 2000-01 seasons

Primary mode for Division 6, as was indicated by Table 1, consisted of relatively significant positive coefficients for January (+.447), February (+.477), and March (+.507). Positive (negative) scores would thus be particularly encouraged by power transformed relative anomalies for those months that were also strongly positive (negative).

Inspecting Figure 2, eight scores above +1.00 are clustered over 1904-05 through 1921-22, none thereafter through 1935-36. Following four additional scores above +1.00 in seven years, through the 1942-43 season, the trend is to negative, nineteen of the next 25 seasons, through 1967-68, showing magnitudes less than zero. Thereafter, noticeably more variability is exhibited. The two most negative scores (-2.44 for 1983-84 and –2.35 for 1971-72, respectively), and the most positive (+2.35 for 1977-78), occur over just twelve seasons. Finally, four scores in excess of +1.00 occur in seven years from 1991-92 through 1997-98.

The 1977-78 maximum reflects the uniformly heavy falls for January, February, and March, matching up well with the significantly positive first component eigenvector coefficients. The 1983-84 extreme negative statistic, conversely, reflects the excessive falls for July-November and December, followed by marked deficits for January, February, and March each (second lowest combined total in the record).

Referencing the Climate Prediction Center list, twelve of the scores greater than or equal to +1.00 were associated with El Nino events, ten with neutrals, and one with a La Nina. Of the scores less than or equal to –1.00, six were related to El Nino's, five to neutrals, and four to La Nina's. The 1983-84 season was a weak La Nina, 1971-72 a neutral, and 1977-78 a weak El Nino.

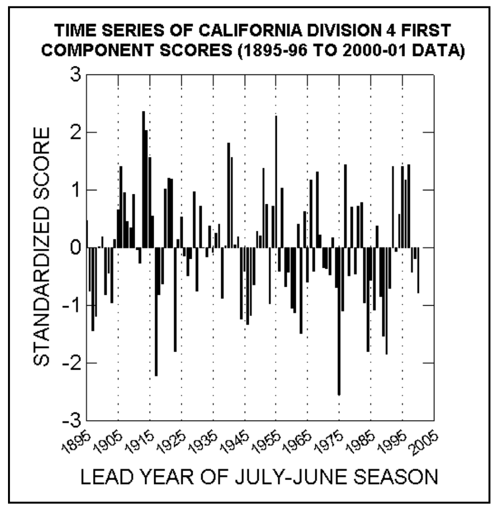

Figure 3. Time Series Plot of California Division 6 ("Central Coast Drainage") First Component Scores for 1895-96 to 2000-01 seasons

Division 4's primary mode, as indicated by Table 3, consists of relatively significant positive coefficients for December (+.570), January (+.559), and April-June (+.329). Figure 3's plot of the standardized scores shows a somewhat more evenly distributed pattern than Figure 2. Over the 1904-05 to 1915-16 interval, positives occur for all but two of the twelve years, the most extreme such magnitude (+2.36) noted for 1913-14 (a moderate El Nino); the 1955-56 season (a strong La Nina) is a close second (+2.29). Lowest score (-2.55) is noted for 1975-76, a strong La Nina year. From 1983-84 through 1991-92, eight of the nine years have negatives, including five at –0.95 or lower.

The 1913-14 maximum reflects the heavy falls for December and January (more than double and triple the average, respectively), this pattern matching up well with the significantly positive first component eigenvector coefficients. The converse is true for 1975-76, the December and January totals each less than 10% of average, respectively.

Eight scores greater than or equal to +1.00 were associated with El Nino events, eight with neutrals, and three with La Nina's. Conversely, six scores less than or equal to -1.00 were related to El Nino's, seven to neutrals, and three to La Nina's.

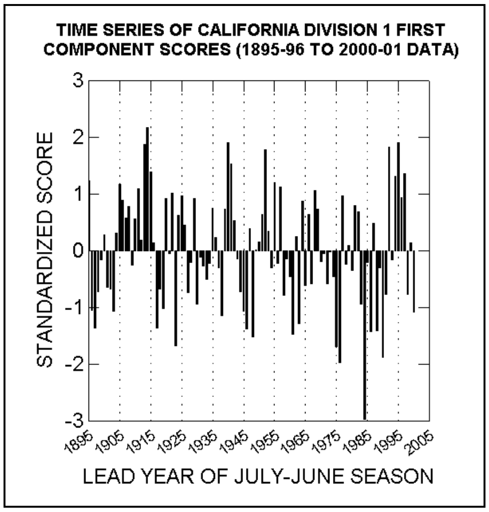

Figure 4. Time Series Plot of California Division 1 ("North Coast Drainage") First Component Scores for 1895-96 to 2000-01 seasons

Primary mode for Division 1 (See Table 5) consists also of relatively significant positive coefficients for December (+.339), January (+.553), and April-June (+.513). From the Figure 4 plot, scores are positive over the 1904-05 to 1915-16 interval for all seasons except one; included among this group is the most positive score of the entire record (+2.18) for 1914-1915 (a neutral season). The more recent years (from the mid-1980's on) show a swing from predominantly negative scores to positive scores. An extreme negative score (-2.98) is indicated for 1984-85.

The 1914-1915 season's anomaly pattern, including 123%, 191%, and 202% percents of average, respectively, for December, January, and April-June, compares favorably with the most positive first component eigenvectors. For 1984-85, December, January, and April-June's rainfall totals are 37%, 10%, and 30% of the 106-year average, respectively. Precipitation is also 202% above average for July-November, the corresponding +1.56 z-score for that period matched against an -0.113 eigenvector coefficient.

Nine scores greater than or equal to +1.00 were associated with El Nino events, six with neutrals, and two with La Nina's. For the less than or equal to –1.00 scores, seven were related to El Nino's, five to neutrals, and seven to La Nina's.

In summary, except for some occasional periods of like-signed clustering and increased variability, there were no obvious long-period non-uniformities in first component scores for the three divisional time-series. El Nino's were represented most often for highly positive scores (29 cases of +1.00 or greater, compared to 24 for neutrals and just 6 for La Nina's). For the highly negatives, the distribution was more even (19 for El Nino's, 17 for neutrals, and 14 for La Nina's).

3.5 Identification of Extreme-most Patterns

Another explorative use of the power transformed standardized data was identification of single-most extreme yearly patterns. The individual year six-variable z-score arrays could be substituted into a matrix expression to generate a multivariate distance statistic that would serve as summary anomaly measurement. The Box-Cox procedure (preceded in some cases by "starting" and/or combining monthly totals) had already transformed the data to approximate univariate normality, and multivariate data that are univariate normal are rarely non-normal in higher dimensions (Johnson and Wichern, 1982). Deviation statistics such as these in this particular application would approximate a chi-square distribution with six degrees of freedom.

The deviation or squared statistical distance of a given standardized observation vector (array of individual observations) from the multivariate mean is defined as (using matrix notation):

$$\mathbf{x}'\,\mathbf{S}^{-1}\,\mathbf{x}$$

where:

- $\mathbf{x}$ is an individual multivariate observation vector
- $\mathbf{x}'$ is the transpose of $\mathbf{x}$.
- $\mathbf{S}^{-1}$ is the inverse of the data set's correlation matrix.

Thus, a given year's generalized deviation statistic would be influenced by the arrangement of individual standardized values in its **x** vector "projected" on the inverse of the overall data set's correlation matrix. Extraction of the most extreme statistic would be an objective means of identifying the most anomalous period-to-period pattern over the 106-year history of a given division.

Tables 8 through 14 identify, by division, the single-most anomalous yearly patterns, with their relevant statistics: year, chi-square statistic, period-to-period actual ("PRCP"), period-to-period transformed ("$PRCP_T$"), and period-to-period standardized transformed ("z").

Table 8: Period-to-Period Distribution of Division 6 Precipitation During **1971-72** (χ^2= 12.709)

	JLNV	DEC	JAN
PRCP	1.33”	6.05”	0.03”
PRCP$_T$	0.30	2.67	-2.01
z	-0.68	+1.42	-2.07
	FEB	MAR	APJU
PRCP	0.22”	0.00”	0.82”
PRCP$_T$	-1.12	-2.04	-1.27
z	-1.34	-2.29	-0.60

Table 9: Period-to-Period Distribution of Division 7 Precipitation During **1915-16** (χ^2= 15.074)

	JLNV	DEC	JAN
PRCP	0.39”	1.89”	7.96”
PRCP$_T$	-0.83	0.72	2.82
z	-2.20	+0.88	+2.47
	FEB	MAR	APJU
PRCP	0.27”	0.98”	0.18”
PRCP$_T$	-1.04	-0.01	-1.27
z	-0.74	+0.15	-1.37

Table 10: Period-to-Period Distribution of Division 4 Precipitation During **1908-09** (χ^2= 17.550)

	JLNV	DEC	JAN
PRCP	3.12”	2.01”	20.83”
PRCP$_T$	1.53	0.80	5.04
z	-0.12	-0.45	+2.65
	FEB	MAR	APJU
PRCP	5.95”	3.63”	0.10”
PRCP$_T$	2.71	1.77	-1.66
z	+0.95	+0.37	-2.61

Table 11: Period-to-Period Distribution of Division 5 Precipitation During **1996-97** (χ^2= 14.748)

	JLNV	DEC	JAN
PRCP	5.85”	6.71”	9.37”
PRCP$_T$	2.78	2.92	3.19
z	+1.09	+1.45	+1.50
	FEB	MAR	APJU
PRCP	0.50”	0.23”	0.74”
PRCP$_T$	-1.51	-1.09	-0.29
z	-0.60	-1.99	-1.73

Table 12: Period-to-Period Distribution of Division 1 Precipitation During **1908-09** (χ^2= 18.768)

	JLNV	DEC	JAN
PRCP	8.97”	5.05”	33.27”
PRCP$_T$	2.99	2.22	6.60
z	+0.11	-0.32	+3.02
	FEB	MAR	APJU
PRCP	12.47”	4.02”	1.28”
PRCP$_T$	4.49	2.03	0.26
z	+1.44	-0.24	-2.00

Table 13: Period-to-Period Distribution of Division 2 Precipitation During **1908-09** (χ^2= 17.093)

	JLNV	DEC	JAN
PRCP	7.51”	3.22”	33.24”
PRCP$_T$	3.70	1.51	5.84
z	+0.05	-0.53	+2.73
	FEB	MAR	APJU
PRCP	10.98”	4.78”	1.23”
PRCP$_T$	4.02	2.32	0.21
z	+1.22	+0.07	-2.03

Table 14: Period-to-Period Distribution of Division 3 Precipitation During **1994-95** (χ^2= 17.545)

	JLNV	DEC	JAN
PRCP	6.14”	1.93	8.25
PRCP$_T$	2.44	0.75	3.13
z	+0.52	-0.29	+1.32
	FEB	MAR	APJU
PRCP	0.95	11.76	7.84
PRCP$_T$	-0.51	3.97	3.12
z	-1.12	+2.93	+2.67

From the tables, the 1908-09 season (a neutral) had the most anomalous period-to-period pattern for three of the seven divisions, the Central Coast Drainage (#4- Table 10), the North Coast Drainage (#1- Table 12), and the Sacramento Drainage (#2- Table 13). In all cases, the extreme statistics reflected the amazingly heavy rainfall totals for January, the continued heavy falls of February, but the marked deficits for April-June. Areal-averaged January 1909 falls for the North Coast Drainage and Sacramento Drainage divisions were each in excess of 33 inches, producing +3.02 and +2.73 z-scores, respectively. The Central Coast also recorded 20.83 inches for January 1909, equivalent to a +2.65 z-score; the April-June z-scores for all three divisions were –2.00 or lower. The North Coast Drainage Division’s 18.768 chi-square statistic, the highest of the seven, is significant at the .01 level for six degrees of freedom.

For the South Coast Drainage Division (#6- Table 8), the 1971-72 season (a neutral) showed the highest chi-square (χ^2=12.709), reflecting the near record heavy December rainfall (6.05”, corresponding to a +1.42 z-score) but pronounced relative deficits for the other five periods, especially January (0.03”; z-score: -2.07) and March (0.00”; z-score: -2.29).

The 1915-16 season (a neutral) exhibited the most anomalous pattern for the Southeast Desert Basins Division (#7- Table 9), attributable to the record heavy fall for January (7.96”; z-score: +2.47) but pronounced relative deficits for July-November (0.39” ; z-score: -2.20) and April-June (0.18” ; z-score: -1.37).

For the San Joaquin Drainage Division (#5- Table 11), the 1996-97 season (a neutral) had the highest chi-square (14.748). This extreme anomaly statistic reflected a pronounced “flip-flop” pattern: relatively heavy falls of July-November, December and

January (+1.09, +1.45, and +1.50 z-scores, respectively) followed by marked deficits for February, March, and April-June (-0.60, -1.99, and –1.73 z-scores, respectively).

Finally, the 1994-95 season (a moderate El Nino) showed the most extreme pattern for the Northeast Interior Basins Division (#3 - Table 14). This was attributable to the heavy rainfalls of January and March, the latter a record, sandwiched around a dry February (z-scores of +1.32, +2.93, and –1.12, respectively), followed by a very wet April-June (z-score: +2.67).

4. Summary

Using normally transformed, standardized precipitation data, Principal Components Analysis (PCA), and varimax rotation, the existence and character of month-to-month modes in July-June precipitation variability were investigated for the complete set of seven NCDC California climatic divisions for the 1895-96 through 2000-2001 seasons. Results resolved, for each division, three components that explained the variance of a full-fledged original variable. Eigenvalue magnitudes and differentiations between them were modest, the first three modes, on average, explaining about 60% of the variance. The nature of the modes changed with general latitude band, but topographical influences were undoubtedly important as well. On a mode-to-mode comparative basis, the southernmost divisions ("South Coast Drainage" and "Southeast Desert Basins") had the most distinctive eigenvector coefficient configurations. Time series plots were constructed of first component scores, the most extreme magnitudes (positive and negative) generally being associated with El Nino or neutral events. Using multivariate statistical distance formulation, the most extreme individual yearly patterns were also identified, division-by-division. Six of these were associated with neutral episodes.

5. Acknowledgements

The California Divisional Data and Figure 1's map were downloaded by accessing the NOAA National Climatic Data Center link:
http://www.ncdc.noaa.gov/onlineprod/drought/main.html

The NCEP Climate Prediction Center page with the list of ENSO events is accessed from the link:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears_1877-present.html

6. References

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