One Hundred Years of Extreme Rainfall Data

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This study started as a search for California rain records with 100 years of daily rain data. Seventy six records were found which were nearly complete. They covered the entire State and the years 1898 to 1997. The rain records for this study are listed in Table 1. A further object of this study is to evaluate long term trends in flood producing rainfalls and the forces that influence them. Still another objective of this study is to celebrate 100 years of Climatological Data which publish the efforts of a vast corps of volunteer weather observers; and the National Weather Service who administer it.

The earliest rain record for California were from Monterey during the late 1840's. The oldest continuos rain records are from San Diego, San Francisco and Sacramento with rain data since about 1850. The State's weather record archive was lost in the San Francisco fire of April 1906. Fortunately regular publication of daily weather records started in 1897 with the monthly publication Climatological Data. The seventy six records of this study contain some estimates of missing values. These were for less than about two percent of the total time; including the May to September portion of the 1996-97 water year.

An index of flood producing rainfalls was developed using the maximum rainfall for one day, 10 and 30 consecutive days as well as the total yearly rain for the October to September water year. Each of these are described below:

The average maximum daily rainfall at the 76 rain records is 2.26 inches. The 100 year trend is at the rate of plus .06 inches per century. Before 1947 there were 4 years when the yearly maximum was above 3 inches, since 1948 five years exceeded have 3 inches (Figure 1).

The average maximum rainfall for 10 consecutive days at the 76 rain records was 5.71 inches. The 100 year trend is at the rate of plus .17 inches per century. Before 1947 there was 1 year above 8 inches, since 1948 6 years exceeded 8 inches (Figure 2).

The average maximum rainfall for 30 consecutive days at the 76 rain records was 8.79 inches. The 100 year trend is at the rate of plus .41 inches per century. Before 1947 there were 7 years when the yearly average was above 12 inches, since then 9 years have exceeded 12 inches (Figure 3).

The average water year total rainfall at the 76 rain records was 23.09 inches. The trend for the 100 years is plus 1.76 inches per century. Before 1947 there was one year when the yearly rainfall was above 34 inches, since 1948 there have been 5 years where it has exceeded 34 inches. (Figure 4).

Trends in rainfall for the State over the last 100 years have been for increased rain in the more recent 50 years. This is true when looking at the maximum one day, the maximum 10 days, the maximum 30 consecutive days or the trend in total annual rain.

The trend graph of the total water year rainfall was decomposed into individual records. There were 24 stations out of the 76 which had a negative trend for the 100 years of this study. These stations are clustered in San Diego and Orange Counties, along the Sierras

and in general in the coastal areas. (Figure 5). In general the Coastal regions show a decreasing rain trend and the Central Valley region from Fresno north shows a definite increase in annual total rain. The high degree of inter-station coherence in the trends from adjacent stations suggests real climatic trends are being monitored, rather than the noisy signals of poor records.

There is no one agency in California responsible for archiving all of the State's weather records. There are dozens of agencies keeping rain records in California for their own use and to their own standards. This means that there is little uniformity in equipment or observation time or record keeping.

Keeping a can and a ruler to measure rain and regularly recording observations makes each weather observer the world's leading expert on how much rain occurred at that location. Sharing these observations is a valued public service. Our State's water plan is anchored largely in the records of thousands of volunteer rainfall observers. Observers have been quite generous over the years in sharing their records. We are grateful for their generosity.

Now we have new tools for rain measurement. Historic continuity in rain measurement is being challenged. Those of us interested in climate change will be watching with care to see how well the new records compare with the old.

Precipitation measurement at its best is only an index of the actual rainfall. Koshmieder reported on aerodynamic errors in rainfall measurement. His research was published in the Monthly Weather Review of January 1934. Koshmieder found a 50% under catch in rain gages in a 26 mph wind. Koshmieder's correction was applied to the rain record at Stonemead, located 11 miles South East of Sacramento. It was found to be under measuring by 13 percent.

My involvement in weather records started on November 18, 1950. That was the day I reported to work for the US Weather Bureau at the Sacramento Post Office building. A monumentally large storm was raging in the Southern Sierra on that day. The resultant flooding washed out a section of the Yosemite Highway. Twenty two stations reported more than a quarter of the years average annual rain fall on that day. This experience sparked my interest in the study of large storms and later led me to a realization of the importance of compiling old rain records.

My (meaning the California Department of Water Resources) rain record archives consists mainly of tabulations of annual extreme values of over 3400 records with more than 110,000 station years of record. There are depth duration frequency tabulations with each data set. The data sets consist generally of annual series extremes for 1, 2, 3, 4, 5, 6, 8, 10, 15, 20, 30 and 60 consecutive days and the annual total. Some stations have short duration data for 5, 10, 15, 30 minutes and 1, 2, 3, 6, 12 and 24 hours as well as the annual total. Some stations have both series and are therefore counted twice in my files.

It has been a goal to compile all available NWS records for each station and bridge the gap between the post 1948 digitized records and the older hand written records. Several county agencies have helped in this project; there is room for more volunteers.

All 3400 of the rainfall data sets with depth duration frequency tabulations are in Excel 5 spread sheets. They fit comfortably on a 100 mb ZIP drive disk in a Macintosh format. They are public domain records. They are available to cooperators on a data

exchange basis, as I am interested in expanding the data base to continue the study in historic rain storms.

The procedures used to calculate return periods was intended to produce uniform results by various workers rather than to produce the most bullet proof statistical analysis. My sins were mainly converting all the individual rain record statistics to deminsionless coefficients and averaging those coefficients over "regions of climatologic homogeneity". The depth duration frequency tabulations are then based on regional averages of the coefficients of variation, skew and kurtosis rather than the sample values calculated from short records. A skew - kurtosis map was used to select Pearson's type III distribution to model rainfall extremes, based on the methods of Elderton from his book "Frequency Curves and Correlation". I have received a great amount of help in this work from Paul Wu, of the Contra Costa County Flood Control District and others.

I have compiled a list of over 650 daily rainfalls in California with 10 inches or more of rain in one day. The earliest one was at Pilarcitos in San Mateo County on December 17, 1871. The latest one was at Wilder Ridge in Humboldt County on January 2, 1997. The San Gabrial Mountains north of Los Angels is the region of California with the most of the State's 10 inch per day rainfalls. The 10 inch per day rainfalls usually occur on the windward slopes of the orographic barriers; up wind from the Pacific Ocean (Figure 6). By contrast there 272 stations reporting "once in a thousand year rainfalls" from about 60 different storms. These 1000 year storms are fairly randomly distributed through out the State (Figure 7). A "1000 year storm" in this study refers to one that is calculated to be about 5 standard deviations above the mean.

The direction of my current studies in historic rain is to evaluate long term trends and to compile storm studies consisting mainly of maps of lines of equal return period of historic storms. The general criteria for a storm study is that there is a station with a rainfall with a return period of 1000 years or that several stations reported the greatest ever rainfalls.

About 60 storms have been have been studied so far (Table 2). The biggest storm in terms of lives lost was the March 2, 1938 storm in Los Angeles County. This was near Pasadena where 87 people lost their lives. This storm produced some of the largest flood peaks ever reported in Southern California.

The biggest storm in terms of dollar loss was the New Years storm of 1997; with flood related losses of over $1.9 billion. For human misery this storm also excelled. Over 100,000 people were driven from their homes before it was over. Brewer reported in his "Up and Down California" that a quarter of the State's assessed evaluation was lost in the flood of 1862. We have little data on the 1862 storm (Table 2).

The biggest storm sequence in terms of the most stations reporting the highest ever rainfall was water-year 1983. Five hundred and ten stations reported the highest ever water-year total rainfall. Two hundred and sixty eight stations reported over 200% of the average yearly rain. These stations were located in all regions of the State.

The biggest storm in terms of the number of stations reporting 10 inch per day rainfalls as well as the wettest one day occurred on January 23, 1943 in Los Angeles County. This was the day when Hoegees and 6 other stations reported over 20 inches of rain in one day.

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Rainfall has increased but rainfall variability in California has increased spectacularly in the last 50 years, as measured by a 10 year running average of the coefficient of variation (CV)(Figure 8). (Note: the coefficient of variation is the ratio standard deviation / mean.) The CV has increased from about .25 before 1950 to about .35 for the last 20 years, based on the 100 year rain index. The big question is---Was this increase in rainfall caused by a more humid climate or was it inadvertent weather modification due to increased atmospheric particulates from our coastal cities? Perhaps it reflects the increased particulates which serve as condensation nuclei from the increased number of volcanoes in recent times?

Increased rainfall due to climate variation is a flood threat to people living in low areas along rivers. Folsom Dam as I recall was intended to offer protection against a 100 year flood when it built in the early 1950's. The level of flood protection offered by Folsom Dam has eroded due to the wetter climate of the last 50 years, since only the records of the dryer previous 50 years were available during the planning for Folsom Dam.

An index of flood producing rainfalls for the American River Basin was developed to compare the present and the previous 50 year periods. It consists of averaging the rainfall from the annual extremes of six stations. These are Lake Spaulding, Soda Springs, Auburn, Colfax, Folsom and Placerville.

A 100 year, ten day rainfall was 17.81 inches based on the 1897 to 1947 period. It has increased to 22.53 inches in the most recent 50 years, as shown on below;

	Return Period in Years	1 Day	3 Day	10 Day	15 Day	30 Day	Year
1898 to 1947	100	5.10	10.28	17.81	21.46	28.67	70.46
1948 to 1997	10	4.77	9.59	15.89	17.96	25.02	66.51
1948 to 1997	15	5.09	10.44	17.18	19.33	26.89	70.46
1948 to 1997	20	5.32	11.01	18.04	20.26	28.14	73.07
1948 to 1997	25	5.49	11.46	18.70	20.96	29.10	75.04
1948 to 1997	50	6.00	15.80	20.66	23.06	31.92	80.81
1948 to 1997	100	6.50	14.09	22.53	25.05	34.60	86.17

There has been a sharp increase in sea surface temperature (SST) of West Coast shore stations (Figure 9), and in the Northeast Pacific Ocean in the last 50 years (Figure 11). This has been accompanied by a parallel increase in the occurrence of tropical cyclones in the region in the same time frame (Figure 10). The number of 1000 year rainfalls that occurred in the State has parallel the increase in the CV of the annual total rainfall (Figure 8).

My speculation is that the increase in coastal SST is be a part of a global pattern which includes a west to east flow of a cold plume of water over the entire North Pacific Ocean centered at about latitude 40°N. This started in the Western North Pacific Ocean, with increased cold water upwelling which for the last 50 years has been moving toward our coast (Figure 11). The trend of SST at 40°N and 145°E is average rate of minus 6.7°F per century, where as at our West Coast shore side SST measurement sites it is heating at the rate of plus 4.9°F. per century (Figure 9). A westerly current would cause the high sea

levels on the West Coast of North America which could suppress cold water upwelling off our shore. That could account for the warmer SST as well as warmer air temperatures in our Coastal Regions during the last 50 years. The long term tide level records could be a source for further verification; but tectonic forces at the tide gage sites have complicated this issue.

The return period for a 100 year rainfall event on the American River for the 1897 to 1947 period compared with one for 1948 to 1997 suggest that the 100 year event for 1897 to 1947 has now been reduced to a 15 to 25 year event. This is why the flood control system was severely taxed in February 1986 to be followed so closely by new near record flows of the 1997 event. The "100 year level of flood protection" on the Lower American River was apparently intended for dryer times.

The 1997 New Years Day Storm was one where Western North America was visited by a strong flow of warm tropical air. The resultant storm dumped over ten inches of rain on top of a snow pack. In the Northern Sierra Nevada the heaviest rainfalls extended from Lake Tahoe north to the Feather River Basin.

The return periods associated with rainfalls of the 1997 New Years Day storm were not spectacular; but some of the stream flows were. The Cosumnes River at Michigan Bar had a peak flow of over 90,000 cfs This was twice the old record. The water surface elevation at Lake Tahoe was at the highest levels since 1917. The highest ever stream flows were reported from many stations.

The 1997 New Years Day Storm was apparently a snowmelt flood similar to those of December 1937, November 1950 and February 1963.

Ray Linsley who once served as a flood forecaster at Sacramento before he became professor of hydrology at Stanford University was right, back in the 1960's when he said, "THE BIGGEST ONE IS YET TO COME".

Table 1

Station Index for Rainfall Trend Study

Stations with 100 Years of Daily Rain Record -- about 2% estimated record.

Station	DA	Long	Lat	Elev	Average Yearly	Avg Max 30 Days	Avg Max 10 Days	Avg Max Day
Antioch	B80	-121.728	37.984	60	12.52	4.92	3.27	1.38
Auburn	A70	-121.069	38.889	1292	34.38	12.42	8.03	2.68
Bakersfield	C00	-119.043	35.427	494	6.03	2.37	1.57	0.85
Berkeley	E40	-122.250	37.867	299	23.46	8.64	5.59	2.24
Betterivia	T12	-120.517	34.917	160	13.55	5.78	3.88	1.77
Big Bear	Y01	-116.975	34.242	6815	35.24	16.19	11.26	5.09
Calistoga	E30	-122.583	38.585	364	37.36	14.87	9.76	3.69
Capay 4W	A80	-122.117	38.705	300	22.37	9.10	6.18	2.42
Cedarville	G10	-120.173	41.528	4670	12.69	3.47	2.29	1.08
Chabot	E40	-122.121	37.730	245	21.82	7.92	5.13	1.99
Claremont PC	Y01	-117.709	34.097	1185	18.06	8.23	5.88	2.70
Colfax	A70	-120.952	39.099	2418	47.25	16.98	10.67	3.54
Crystal Sp	E70	-122.367	37.500	400	25.29	9.28	5.93	2.14
Cuyamaca	Z07	-116.583	32.983	4650	36.80	14.38	9.62	3.96
Davis	A00	-121.775	38.535	60	17.26	6.90	4.54	1.87
Elsinore	Y02	-117.331	33.669	1285	12.39	6.06	4.22	2.00
Escondido	Z04	-117.083	33.117	660	15.53	6.90	4.64	2.01
Eureka	F60	-124.167	40.800	43	37.95	11.22	6.65	2.43
Folsom	A70	-121.161	38.707	350	23.91	8.67	5.51	2.03
Forest Lake	D40	-121.942	36.592	295	17.50	6.34	3.93	1.67
Fort Ross	F80	-123.250	38.517	116	41.28	14.42	8.82	3.41
Fresno	C00	-119.717	36.770	331	10.12	3.99	2.61	1.17
Gilroy	D10	-121.567	37.000	194	20.22	8.18	5.48	2.31
Glendora	U05	-117.859	34.140	822	21.17	9.89	7.00	3.18
Grass Valley	A60	-121.059	39.226	2693	53.37	18.68	11.80	4.05
Healdsburg	F90	-122.833	38.617	101	40.60	16.15	10.52	3.74
Hemet Res	Y02	-116.676	33.669	4355	19.29	7.30	5.02	2.29
King City	D20	-121.133	36.200	320	10.80	4.69	3.20	1.46
Lagunitas	E20	-122.595	37.940	785	49.07	18.49	11.59	4.34
Lake Spaulding	A60	-120.637	39.319	5153	68.10	23.21	14.22	4.63
Lemon Cove	C20	-119.025	36.217	513	13.99	5.22	3.38	1.59
Livermore	E50	-121.806	37.691	405	14.24	5.40	3.50	1.45
Lodi	B00	-121.289	38.116	40	16.87	6.24	3.96	1.64
Los Angeles	U05	-118.233	34.050	270	14.79	7.19	5.07	2.31
Lower Crystal	E70	-122.367	37.533	450	26.99	9.52	6.05	2.28
Marysville	A00	-121.584	39.145	60	20.96	7.74	4.92	1.81
Merced	B00	-120.470	37.315	168	11.80	4.43	2.79	1.20
Modesto	B00	-121.001	37.647	91	11.86	4.24	2.78	1.18
Mt Hamilton	E50	-121.650	37.333	4206	24.94	8.90	5.76	2.18
Mt Shasta City	A20	-122.317	41.317	3544	36.12	12.70	8.32	2.93
Napa	E30	-122.264	38.278	73	24.28	9.09	5.96	2.20
Needles	X13	-114.617	34.767	910	4.67	2.11	1.62	1.05
Nevada City	A60	-121.011	39.258	2600	53.28	19.29	12.08	3.91
Newhall	U03	-118.533	34.383	1240	17.73	9.23	6.83	3.17
Newman	B00	-121.017	37.317	214	10.41	4.09	2.73	1.23
Orland	A00	-122.200	39.750	254	19.30	7.30	4.67	1.95
Parker 6 NE	X14	-114.217	34.183	410	4.55	1.99	1.53	1.03
Paso Robles	T09	-120.683	35.633	700	15.12	6.72	4.59	1.85
Pilarcitos	E80	-122.421	37.547	625	38.93	13.68	8.44	3.20
Placerville	A70	-120.798	38.729	1890	38.48	13.75	8.48	2.84
Quincy	A50	-120.940	39.938	3409	40.00	14.40	9.52	3.28
Red Bluff	A00	-122.250	40.150	341	22.90	8.15	5.01	2.07
Redlands	Y01	-117.191	34.052	1318	13.76	5.86	4.00	1.67
Reno	G70	-119.783	39.500	4397	7.50	2.68	1.97	0.97
Riverside	Y01	-117.378	34.003	990	10.62	4.77	3.27	1.47
Sacramento	A00	-121.483	38.583	25	17.45	6.81	4.41	1.76
Salinas	D20	-121.600	36.667	80	13.11	5.13	3.30	1.35
San Andreas	E70	-122.400	37.583	377	31.86	11.72	7.15	2.70
San Bernardino	Y01	-117.267	34.163	1125	16.23	7.24	4.98	2.16
San Diego	Z08	-117.167	32.733	19	10.32	4.67	3.24	1.47

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San Francisco	E70	-122.417	37.783	52	20.48	7.50	4.77	1.88
San Jacinto	Y02	-116.958	33.787	1560	12.89	5.51	3.77	1.68
San Jose	E60	-121.903	37.342	95	14.09	5.36	3.51	1.61
Santa Barbara	T15	-119.700	34.417	100	18.17	8.78	5.98	2.81
Santa Cruz	D00	-122.017	36.983	125	29.10	11.12	6.94	2.73
Soda Springs	A60	-120.367	39.326	6885	52.40	17.70	10.95	3.71
Sonora	B50	-120.383	37.983	1724	31.78	11.53	7.29	2.51
Stockton	B00	-121.316	38.000	12	14.68	5.43	3.54	1.42
Sweetwater	Z09	-117.008	32.693	250	11.26	4.61	3.17	1.48
Tejon Rch	C00	-118.744	35.027	1425	11.14	4.02	2.49	1.27
Turlock	B00	-120.850	37.491	115	11.78	4.39	2.79	1.22
Tustin	Y01	-117.782	33.731	118	12.55	5.75	3.98	1.86
Ukiah	F90	-123.200	39.150	623	36.54	13.75	8.54	2.90
Upper Crystal	E70	-122.350	37.500	300	27.46	9.78	6.19	2.29
Vacaville	A00	-121.967	38.400	104	24.40	9.99	6.66	2.70
Willows	A00	-122.200	39.533	140	17.58	6.77	4.39	1.89
Average		-120.409	37.041	1122	23.09	8.79	5.71	2.26
Max		-114.217	41.528	6885	68.10	23.21	14.22	5.09
Min		-124.167	32.693	12	4.55	1.99	1.53	0.85
Coef of Variation					0.57	0.52	0.50	0.42
Ciunt		76	76	76	76	76	76	76

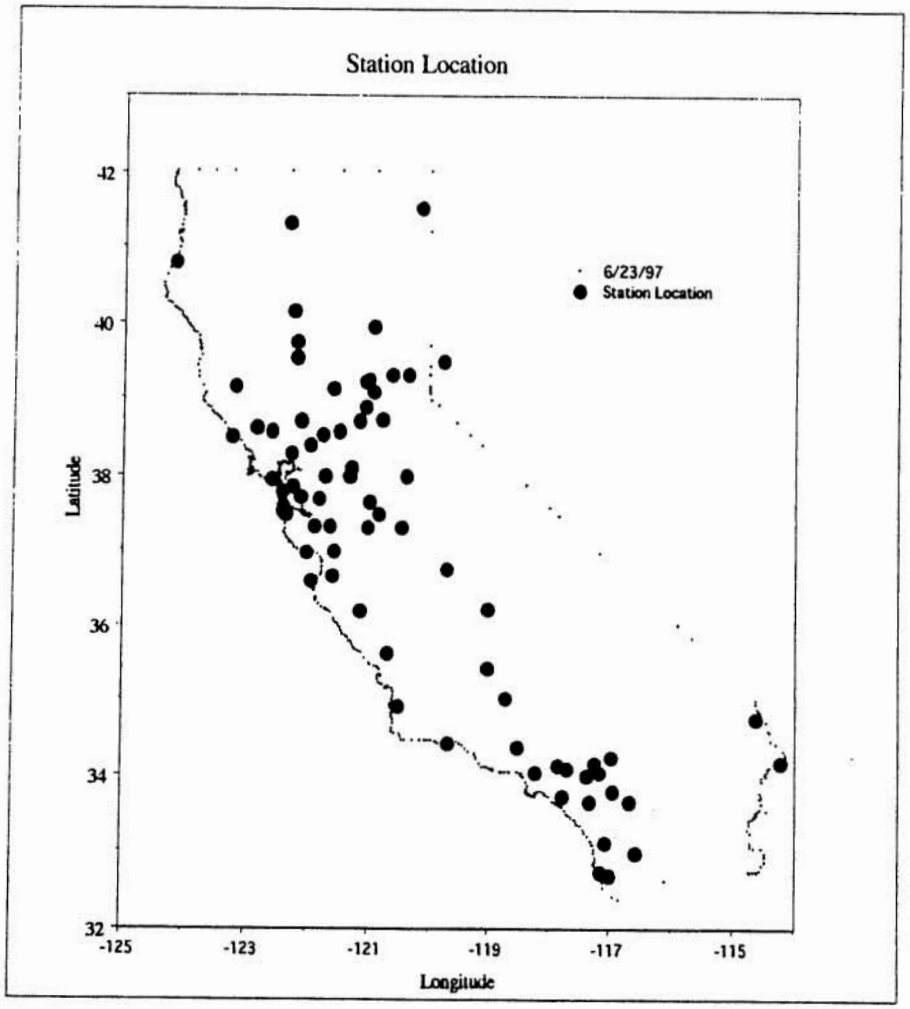


Table 2

Summary of 1000 Year Rainfalls in California

Year	Month	Day	Storm Duration Days	Lives Lost	Damage $ Millions	Counties Effected	Number of Stations Reporting: Highest Ever Rain	10 inched Per Day	1000 Rainfalls	Maximum Rain: Inches	RP 1000 Yrs	Station With Highest Return Period
1861	12	23*21	30	1/4 assessed value of state			2		2	28.25	370.0	San Francisco
1866	12	19	1				1	0	0	9.18	0.6	San Francisco
1871	12	19	1					2	2	27.16	360.0	San Andreas Lake
1874	11	22*23	2				1	0	1	18.02	1M+	Fort Ross
1880	4	30	1				1	1	1	15.70	3.5	Sacramento
1885	11	18-19	2				1	0	1	6.40	10M+	Mendota Dam
1889	10	12	1				1	0	1	7.58	73.0	Encintias
1890	Wtr Yr		365				28		8	138.25	6.6	Newman
1891	2	23&24	2				2	2	2	32.20	22.0	Big Bear Lake Dam
1891	8	12	1				1	1	1	16.10	1M+	Campo
1898	9	26	1				2	0	1	3.89	2.7	Tulare
1906	12	11	1				8		1	8.66	10.0	Forest Lake
1909	1	1*20	20				9	2	2	57.41	12.2	La Porte
1911	1	10*15	6				15		0	19.63	0.9	Livermore
1913	12	31	1				8	5	0	11.48	0.2	Calistoga
1916	1	2	1				3	0	2	9.40	42.0	Chico
1916	1	14	1				1	0	1	6.37	21.0	Bellota
1916	1	14*18	15	22	4.5		24	10	6	37.06	6.7	Descansio RS
1918	9	12*14	3				12	0	2	7.12	2.2	Antioch
1921	12	5Da	5				4	5	0	28.81	0.5	Werner Springs
1925	4	4	1				1	0	1	4.00	6.3	Fancher Ranch
1927	2	13*17	4				39	4	6	26.60	6.6	Morena Dam
1932	9	28*1		15	1							Techachapi
1933	12	31*1	2	40	5		14	16	2	19.49	1.4	Anza Foothill Rch
1937	2	4*7	4				10	1	0	22.85	0.5	Riverside
1937	12	10&11	2		15		32	5	2	20.50	2.3	Alturas
1938	3	2	1	87	78		13	32	0	15.96	0.5	Riverside
1939	9	24	1		1.5		2	0	1	6.33	16.6	Indio
1939	9	5&6	2				7	0	3	6.45	55.0	Brawley 2 SW
1941	Wtr Yr		365				47		7	86.10	5.8	Willows
1943	1	23	1			3	171	64	12	26.13	8.3	Hoegees
1950	10	20	1			1	4	2	1	11.50	2.2	Orick
1950	11	18	1	2	32.2		31	5	9	13.16	23.0	Calaveras Dam
1955	12	17*27	10		200		167	19	20	49.20	5.4	Lake McKenzie
1958	4	3	1			1	3	0	1	5.72	300.0	Oakdale Woodward
1959	9	18	1				2	5	0	12.57	0.6	Summit City
1962	10	11*13	3	56	250		221	23	24	25.78	6.8	Upper San Leandro Filters
1963	1	30*01	3	10	18.5		52	7	5	23.25	33.0	Florence Lake
1964	12	19*24	6		213	31	80	35	7	32.60	370.0	Gaxelle
1966	12	2*7	5		28.8	7	42	19	11	30.60	130.0	Kern River Intake SCE
1969	1&2		60	41	300	40	299	50	20	88.50	8.4	Independence
1970	12	3	1				1	1	1	12.60	130.0	Harrison Gulch RS
1971	8	22	1				1		1	4.00	0.8	Eagle Mtn
1974			1					1	1	10.10	2.0	Fieldbrook 4D rch
1976	9	10	1	5	150	3	13	1	0	12.10	0.7	Meca
1977	8	16	1	5	25	2	21	0	3	7.80	640.0	Yuma Valley AZ
1978	2	10	1	18	120	7	76	7	16	13.31	28.0	Buttonwillow
1980	2	14*21	8	18	316	8	133		0	31.84	0.9	Sage
1980	12	3	1		241		2	1	1	12.00	500.0	Fergerson Ranch
1982	1	4	1	20	651		104	16	9	15.20	5.4	Ben Lomond Lf
1982	6	18	1Hr				1			4.41	1+	Frmi Ridge
1983	3	1	1Hr				1		1	3.00	10+	Bel Air Hotel
1983	8	17	1Hr				1		1	3.83	10+	Lytle Creek @ Foothill
1983	Wtr Yr		365		523		507	8	44	188.50	190.0	Kelseyville
1986	2	11*20	10	13	758		187	11	11	49.44	94.0	Atlas Road
1988	1	17	1				1	0	1	4.10	18.5	Newman
1993	1	5*19	15	20	600		148	1	12	37.89	9.1	Mission Creek
1994	5	5	1				1		1	6.05	1.1	Darrah Springs
1994	11	5	1				2		1	6.76	1.1	San Rrancisco R
1995	Wtr Yr		365				95	9	3	132.49	4.3	Black Butte Ranch
1995	1	7*12	6				49	6	1	35.18	2.4	Greenville
1995	1	10	1	17	741		53	3	7	11.60	4.0	Rancho Cordova JF
1995	3	10	1	16	1,090		56	2	6	12.44	65.0	Morrow Bay FD
1995	12	12	1				10	3	1	10.74	0.6	Clear Lake 4 W
1996	5	16	1				1	0	1	5.33	5.0	Camp Pardee
1996	12	12	1				2	0	1	6.32	0.24	Eureka
1996	12	20	15				22	12	1	47.92	1.3	La Porte
1997	1	1	1	8	1,900	43	28	14	1	13.08	0.8	Antelope Lake
Average				23	331	13	44	7	4	26	59	
Max				87	1,900	43	507	64	44	189	640	
Count				18	25	11	65	55	66	67	61	

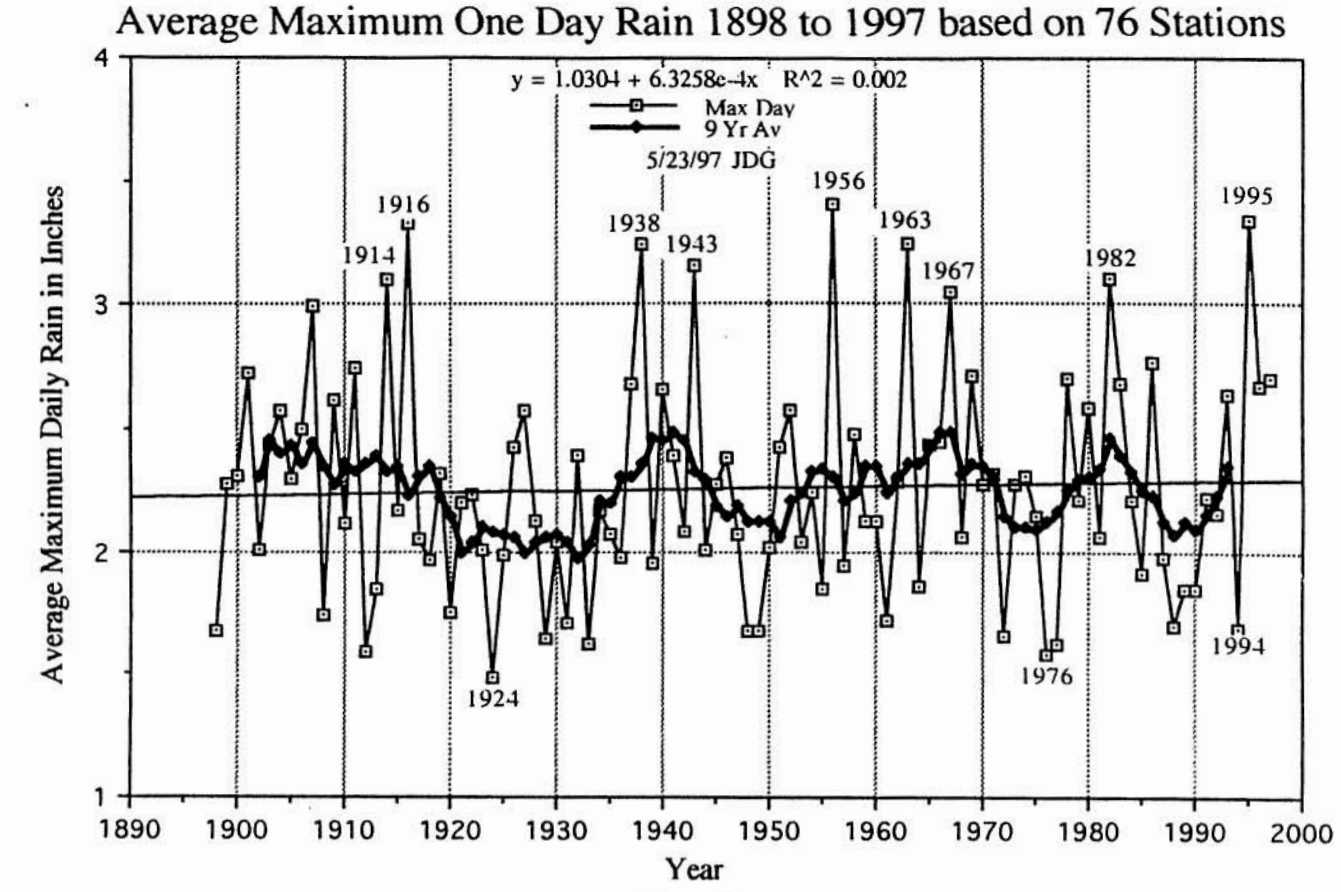
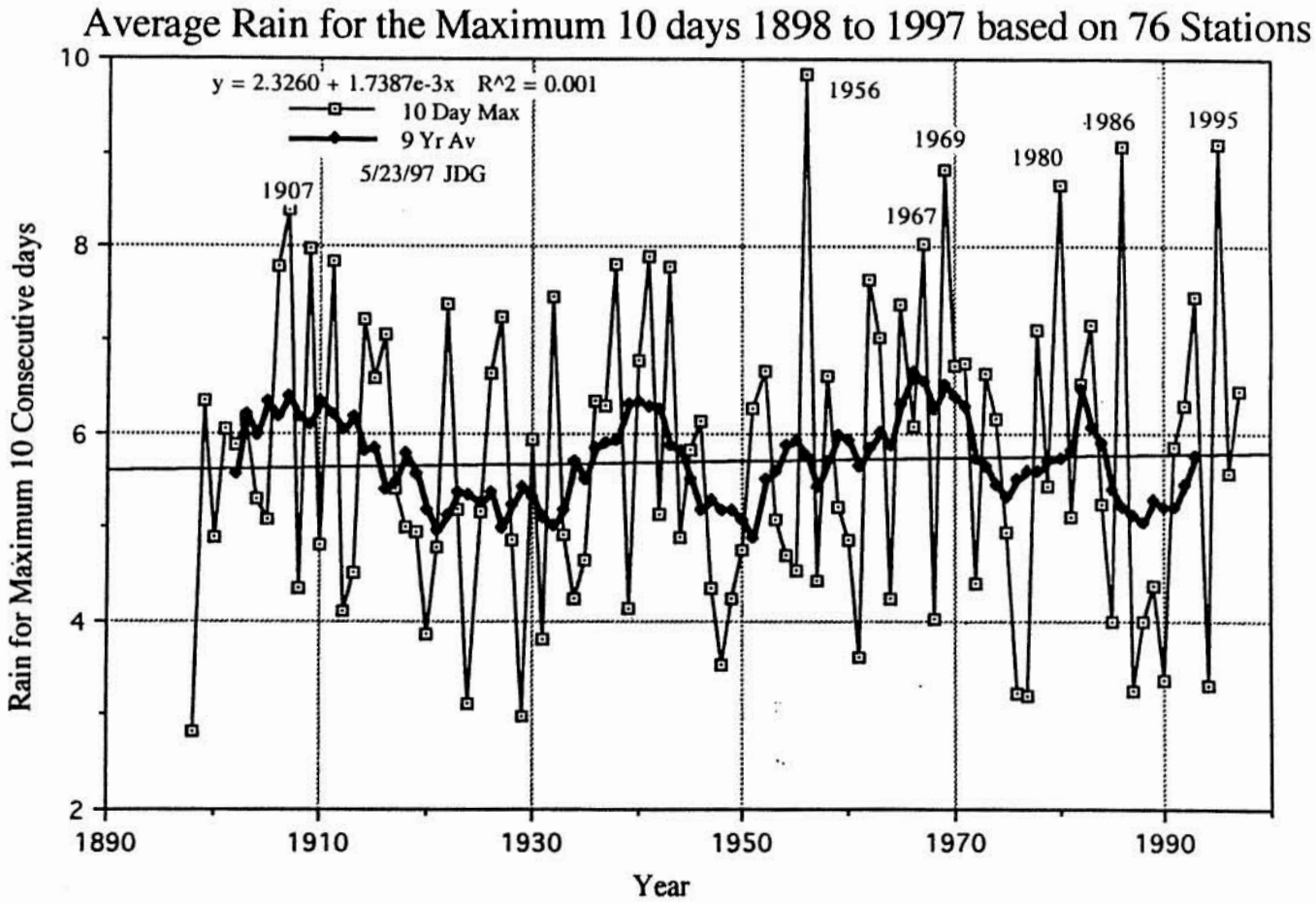

Average Maximum One Day Rain 1898 to 1997 based on 76 Stations
y = 1.0304 + 6.3258e-4x R^2 = 0.002
Max Day
9 Yr Av
5/23/97 JDG
1914
1916
1924
1938
1943
1956
1963
1967
1976
1982
1994
1995
Average Maximum Daily Rain in Inches
Year
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
1
2
3
4

Figure 2


Average Rain for the Maximum 10 days 1898 to 1997 based on 76 Stations
y = 2.3260 + 1.7387e-3x R^2 = 0.001
10 Day Max
9 Yr Av
5/23/97 JDG
1907
1956
1967
1969
1980
1986
1995
Rain for Maximum 10 Consecutive days
Year
1890
1910
1930
1950
1970
1990
2
4
6
8
10

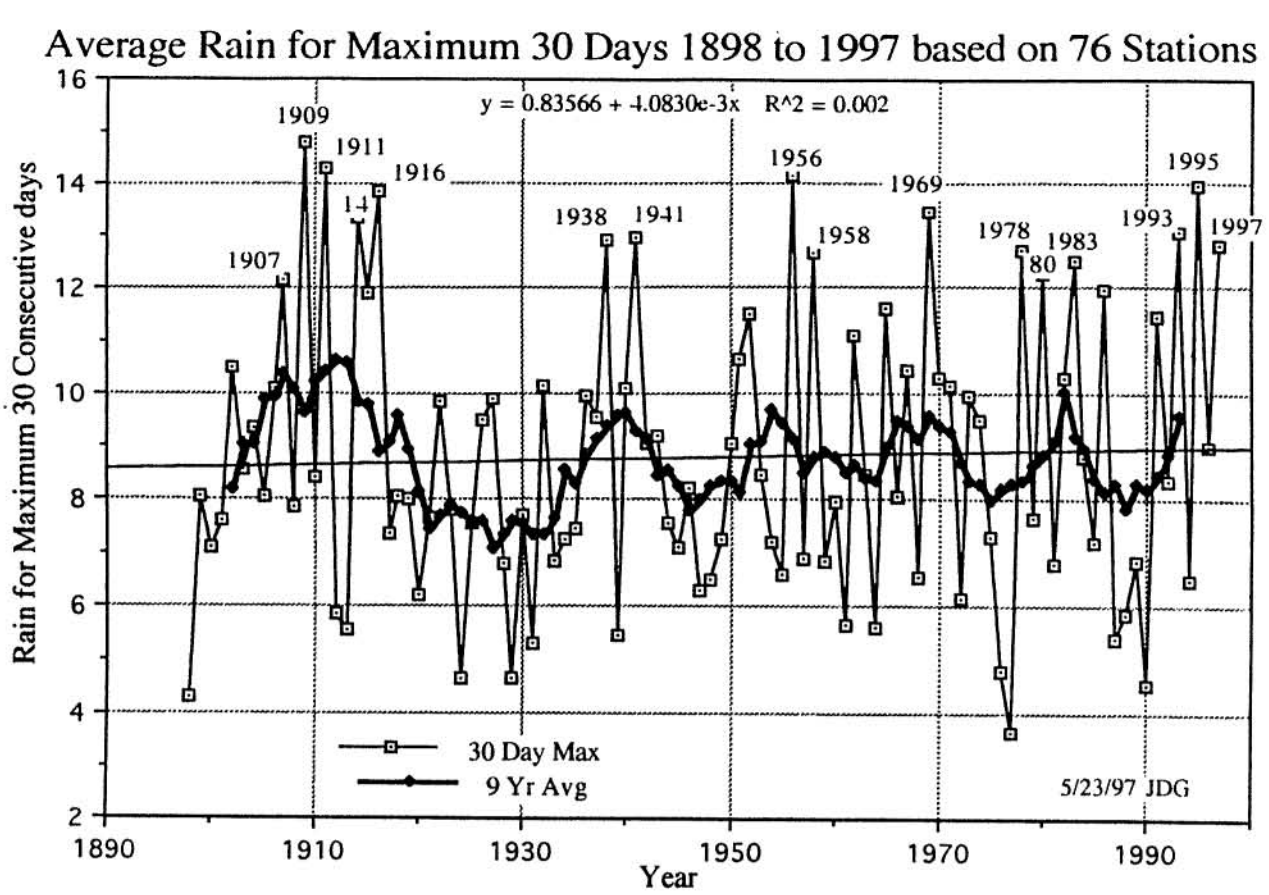

Average Rain for Maximum 30 Days 1898 to 1997 based on 76 Stations
y = 0.83566 + 4.0830e-3x R^2 = 0.002
Rain for Maximum 30 Consecutive days
Year
1909
1911
1916
1907
1938
1941
1956
1969
1958
1978
1983
1980
1993
1995
1997
30 Day Max
9 Yr Avg
5/23/97 JDG
16
14
12
10
8
6
4
2
1890
1910
1930
1950
1970
1990

Figure 4

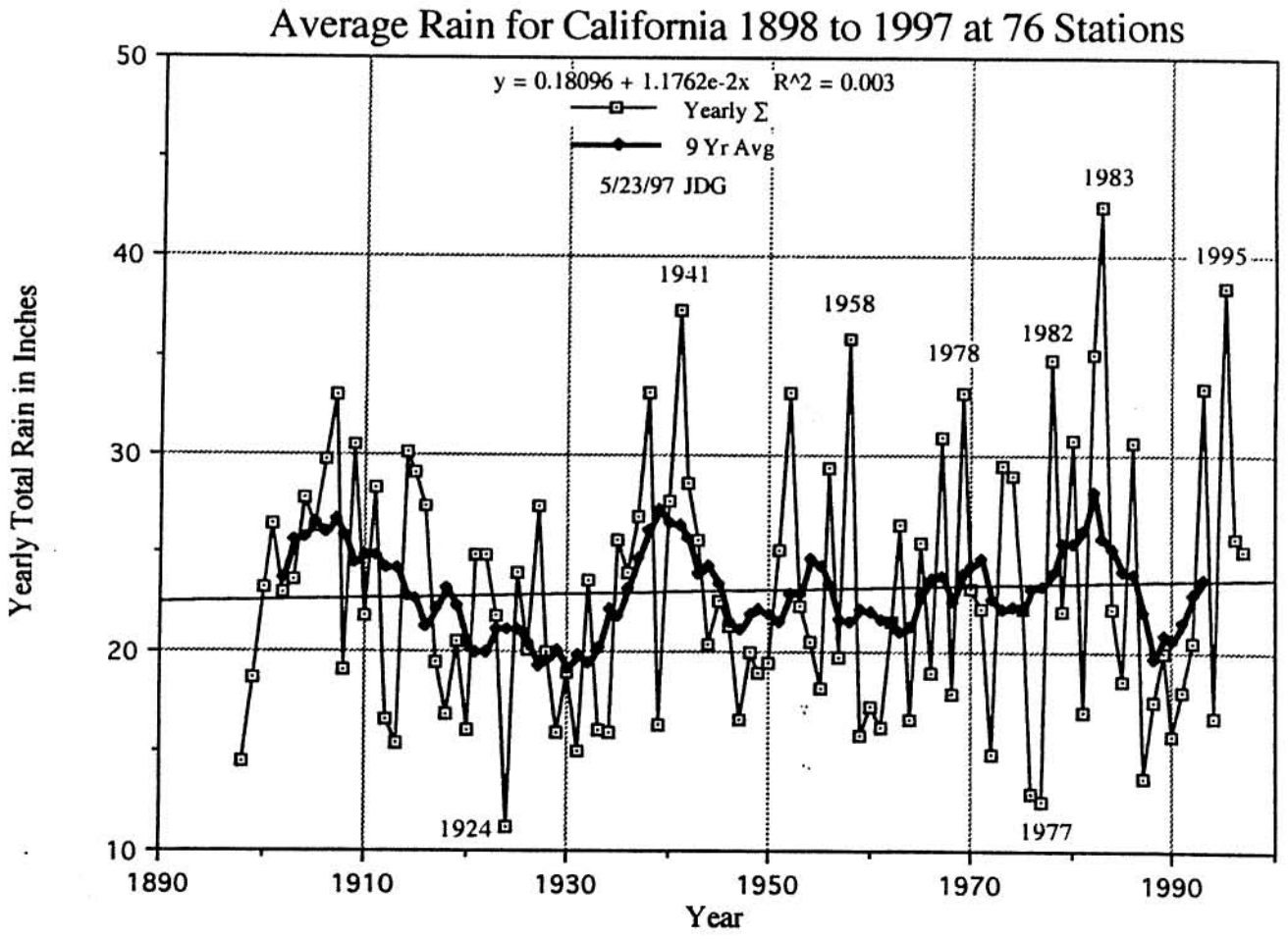

Average Rain for California 1898 to 1997 at 76 Stations
y = 0.18096 + 1.1762e-2x R^2 = 0.003
Yearly Σ
9 Yr Avg
5/23/97 JDG
Yearly Total Rain in Inches
Year
1983
1995
1941
1958
1978
1982
1924
1977
50
40
30
20
10
1890
1910
1930
1950
1970
1990

Figure 5

100 Year Rainfall Trend in California

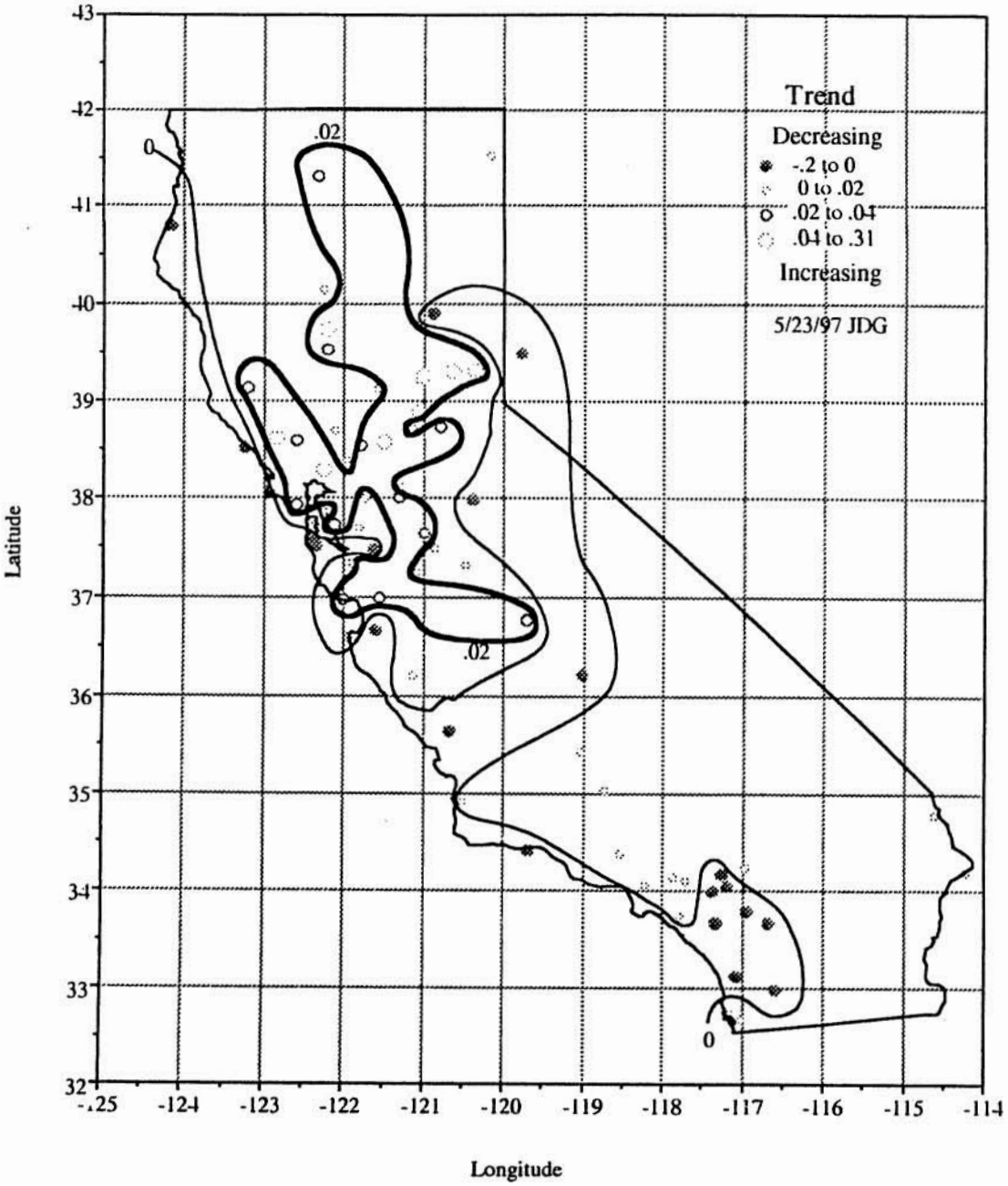
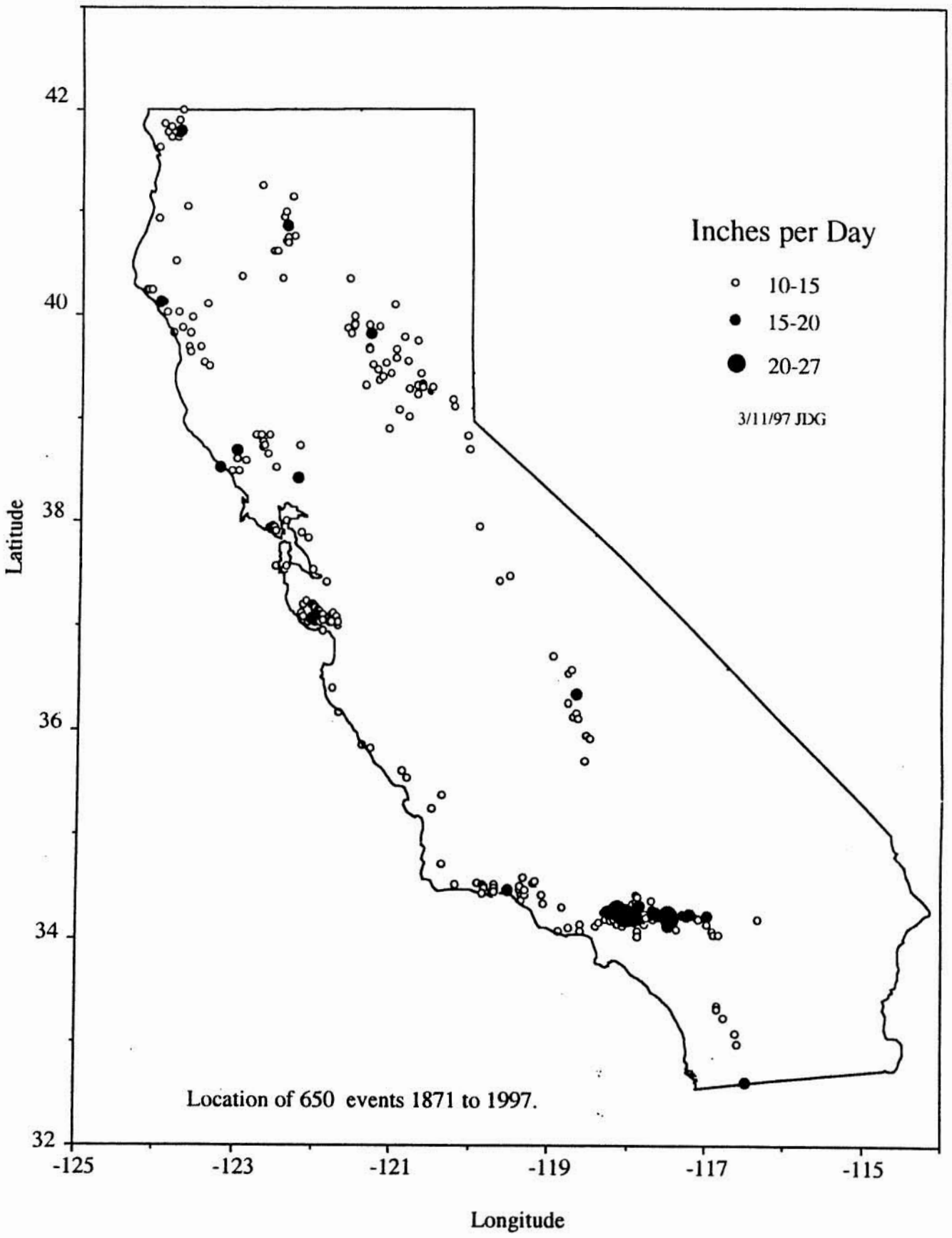


Figure 6

California's Ten Inch+ per Day Rainfalls



Location of Stations with 1000 Year Rainfalls in California

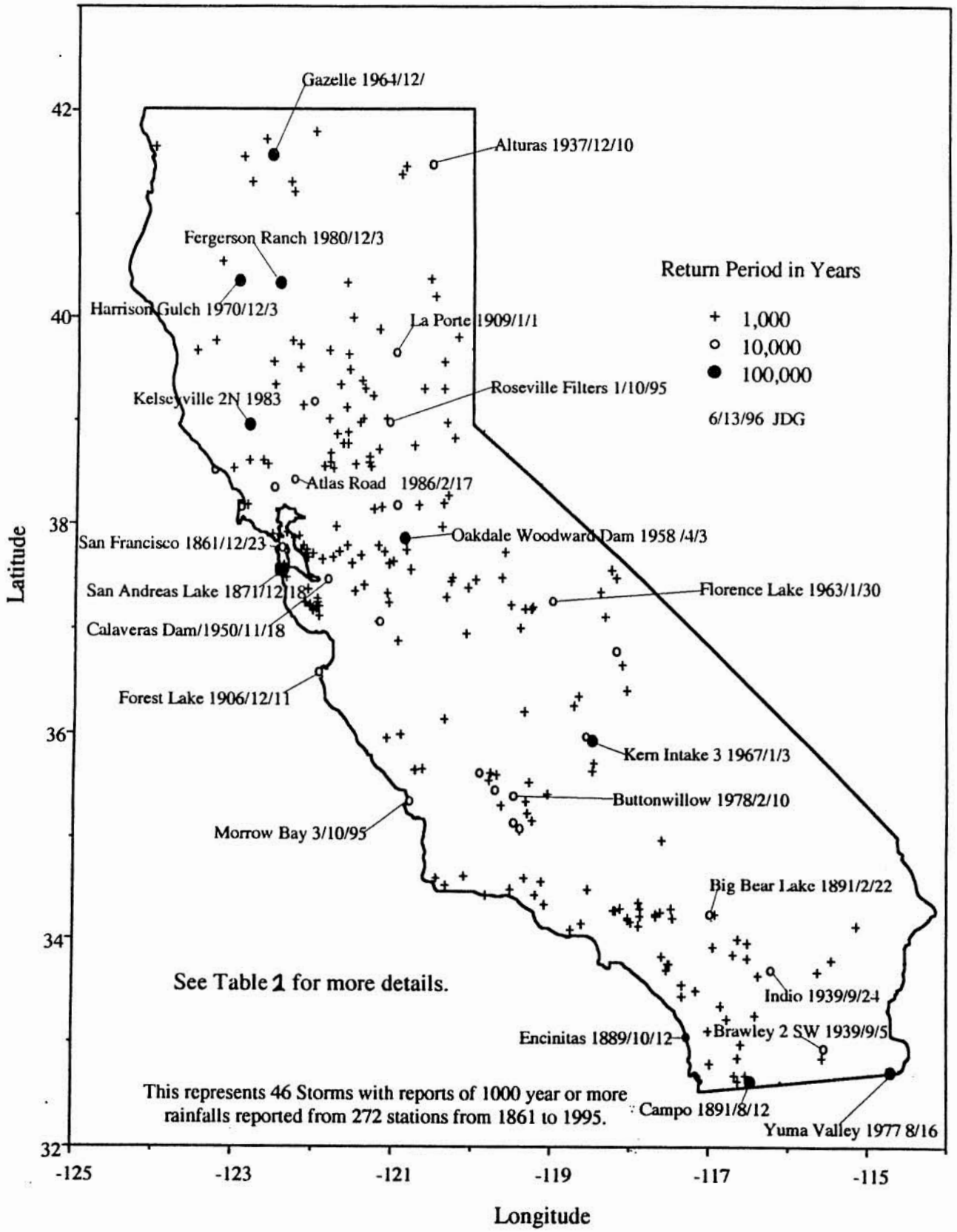


Figure 8

California Rainfall Variability and Sever Storm Frequency Compared

Based on 76 records with 1890 to 1997.

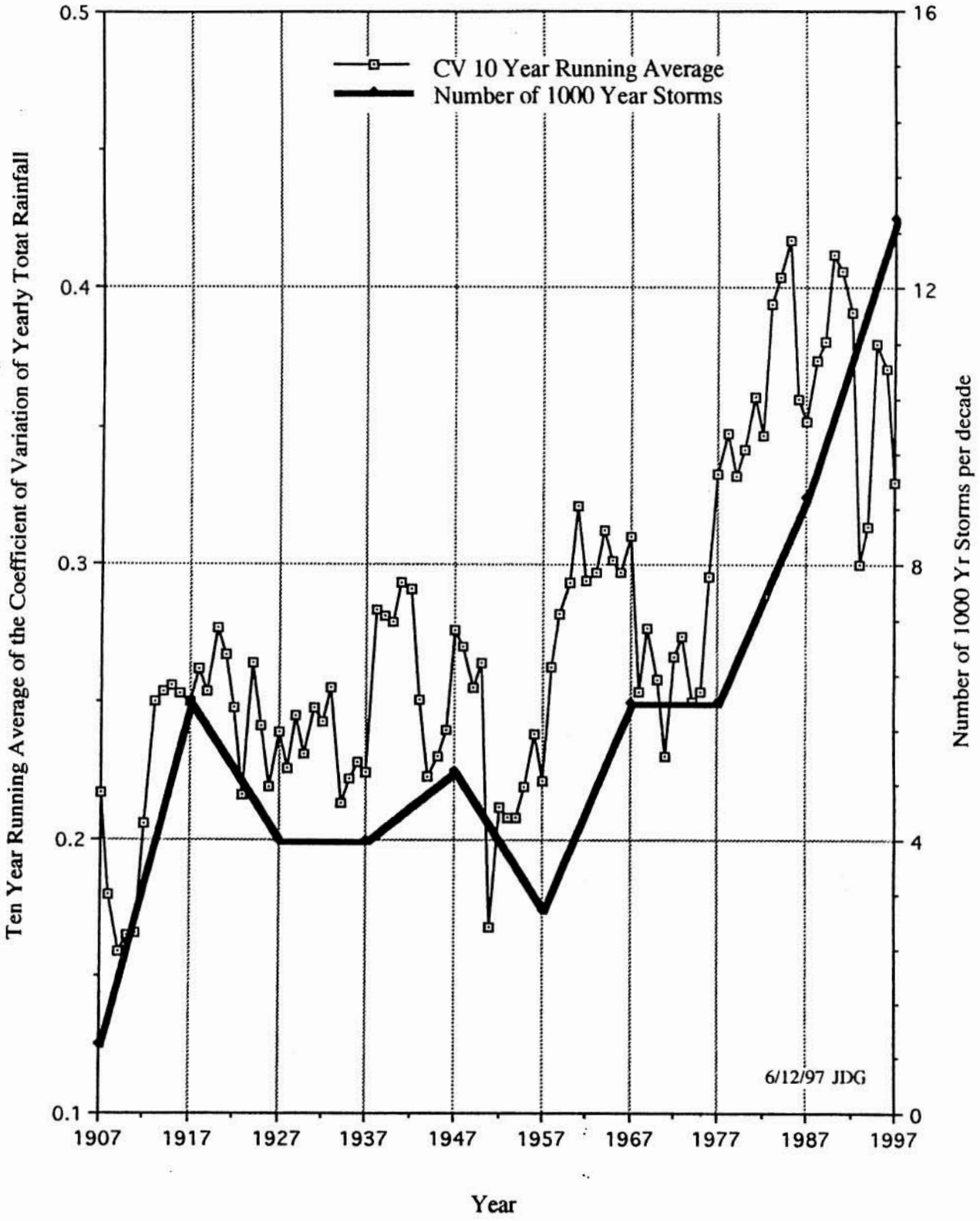


Figure 9

Trends in Sea Surface Temperature in the North Pacific Ocean at 40° N.

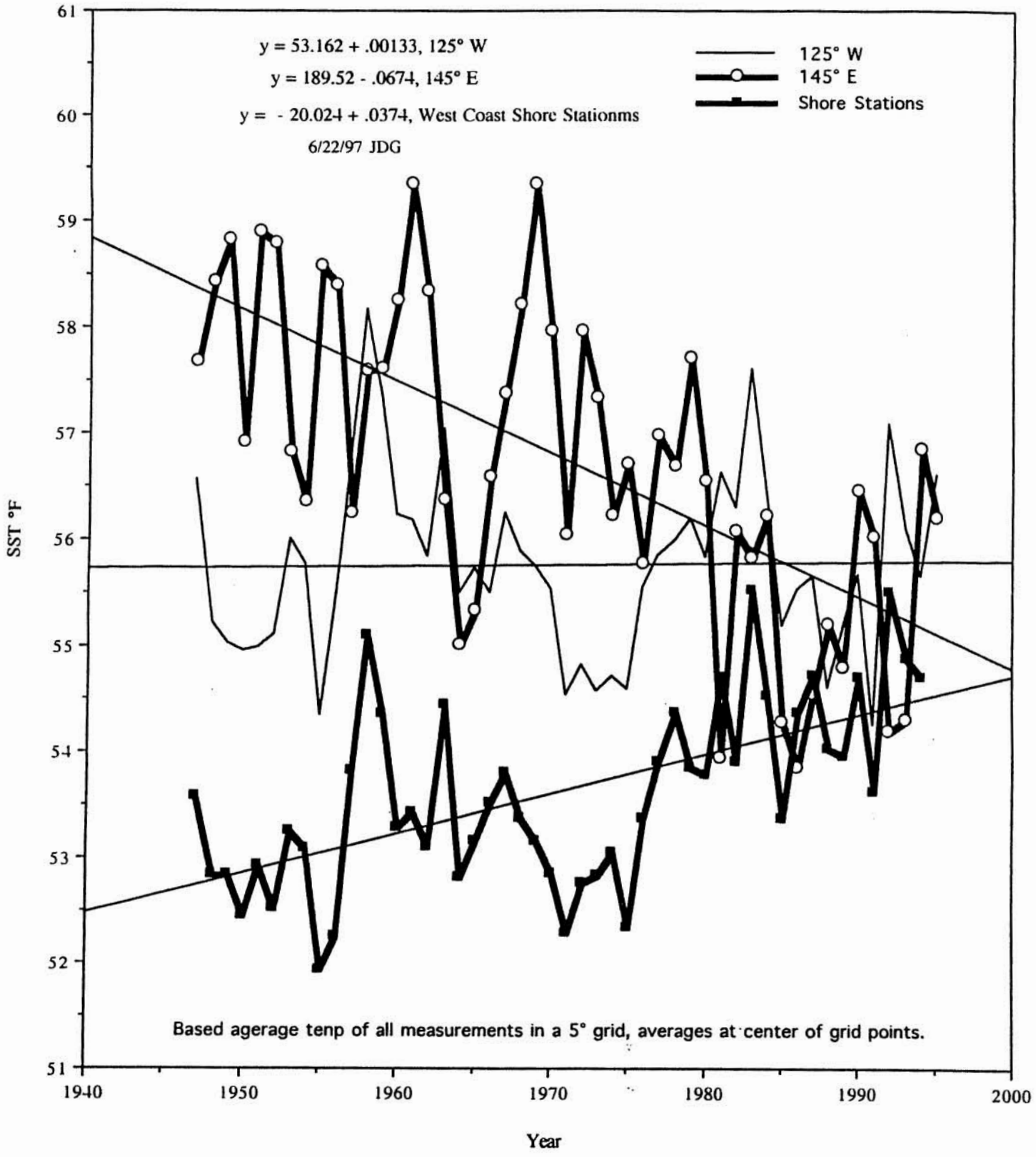
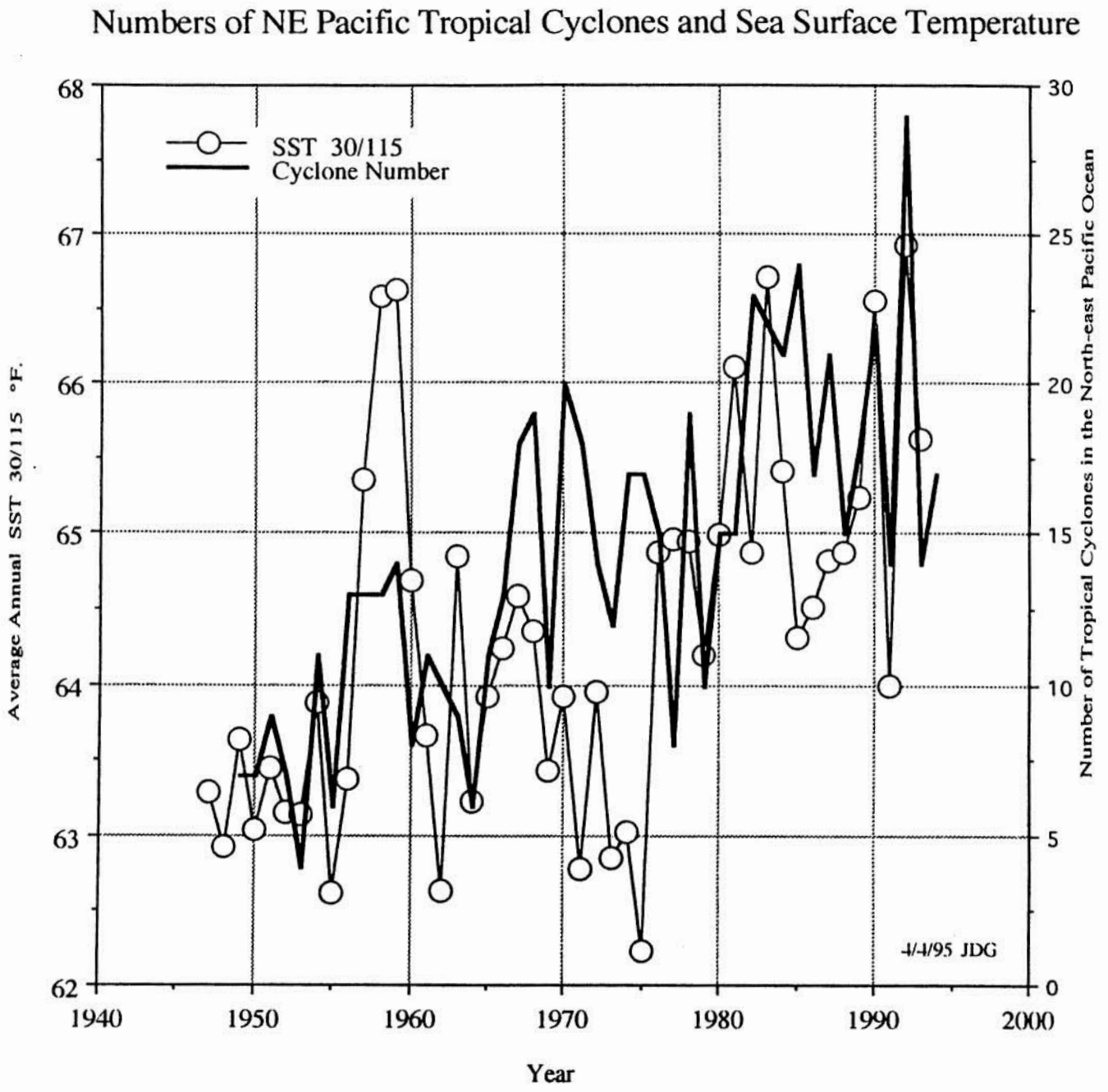
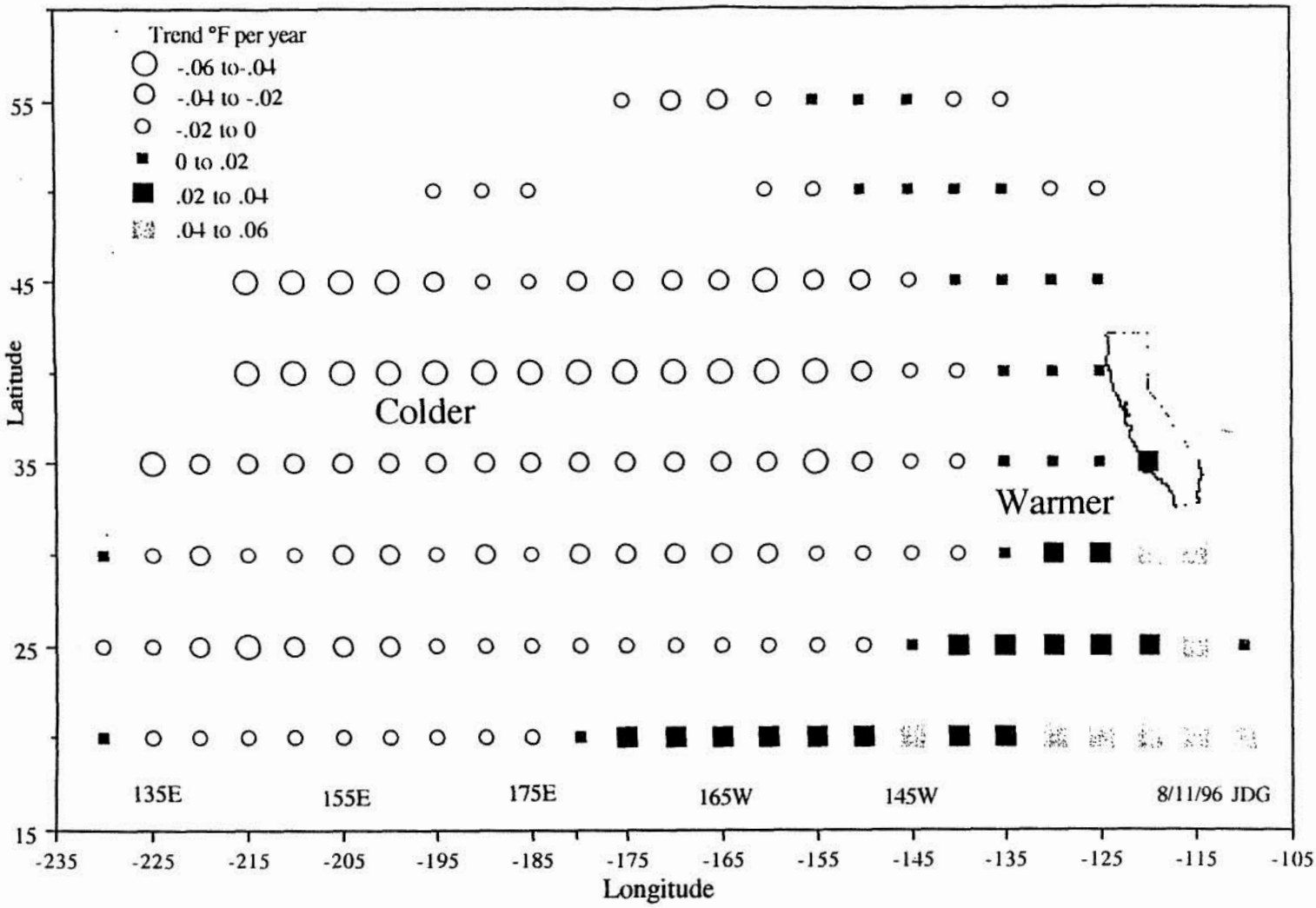


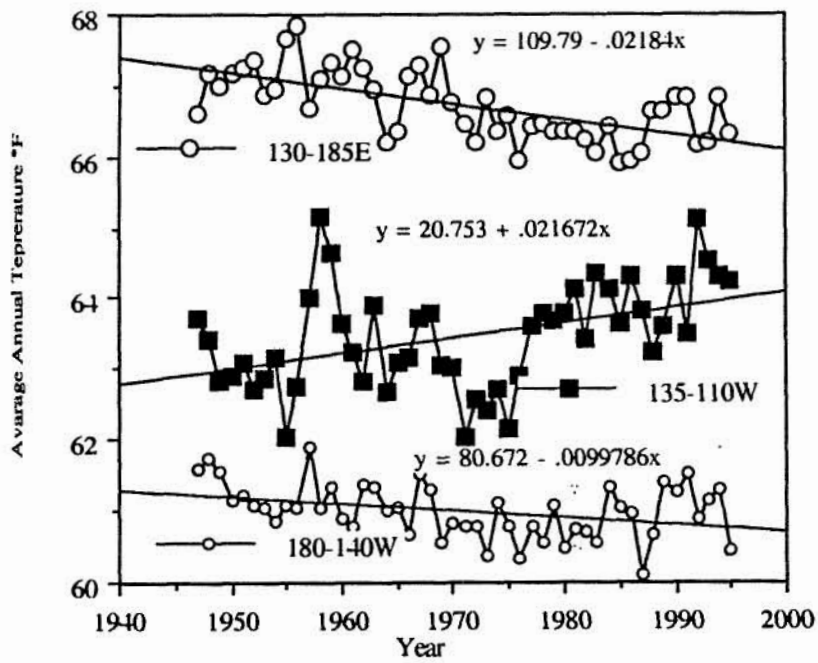
Figure 10


Numbers of NE Pacific Tropical Cyclones and Sea Surface Temperature
SST 30/115
Cyclone Number
Average Annual SST 30/115 °F.
Number of Tropical Cyclones in the North-east Pacific Ocean
Year
4/4/95 JDG
68
67
66
65
64
63
62
30
25
20
15
10
5
0
1940
1950
1960
1970
1980
1990
2000

Trends in North Pacific Sea Surface Temperature from 1947 to 1995



Sea Water Temperature North Pacific 20 to 50°N



Temperature trend at 160 - 5° grid points in the Pacific Ocean between 20 and 55°N.