Air Temperature Trends in California

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"Greenhouse heating" of the atmosphere due to trace gases seems apparent to those who model with averages but not to those who examine individual temperature records. Temperature trends are on the minds of all those concerned with the environmental influence of the increasing human population. The big problem remains — where and how do we take the Earth's temperature?

Landsberg (1981) reported on Luke Howard's study of urban/rural temperature differences for London in 1807 to 1816, which were clearly attributed to urban heat island effects associated with coal burning and severe atmospheric pollution. Landsberg's book, *The Urban Climate*, is a landmark example of the hundreds of reports on urban heat islands throughout the world.

Jones *et al.* (1982) reported on Northern Hemisphere temperature averages based on the World Weather Record dataset, described by Quayle (1989) and compiled by Jenny (1975), in which California was represented by seven stations. In 1986, Jones *et al.* expanded the World Weather Record to include stations in the western United States compiled by Bradley *et al.* (1982). More recently, Hanson and Lebedeff (1988) incorporated the compilation and corrections of the U.S. Historical Climatological Network by Quinlan *et al.* (1987). The network has 33 California records for the 1910 to 1989 period.

In California, there are 112 temperature records for 1910 to 1989; all of them are used here to examine trends in annual temperature. These records are part of the National Weather Services network, and are published by the National Climatic Data Center in the monthly *Climatological Data*. Not all of the California temperature records were problem-free. Missing monthly values were estimated from nearby stations in a few cases, and some annual values were estimated as well. The intent was to develop a data series that resembled the observed data, with no corrections for station moves or changes in time of observation.

California temperature records are averaged in various ways here to provide an overview of the effects of averaging temperature data. Temperature trends of individual stations are plotted on Figure 1. Areas of upward temperature trends correspond with areas containing California's major population centers.

The average temperature of all 112 California records, plotted on Figure 2, has an 80-year trend of +0.014°F per year. The highest average temperature was in 1934, and lowest mean annual temperature was in 1948.

The 112 temperature records were also averaged by county population. Three size categories were selected based on the 1989 population:

In: J.L. Betancourt and V.L. Tharp, editors. 1991. *Proceedings of the Seventh Annual Pacific Climate (PACLIM) Workshop, April 1990*. California Department of Water Resources. Interagency Ecological Studies Program Technical Report 26.

Category	Population Range	Temperature Trend
Small Counties	4,000 to 99,000	+0.005°F
Mid-size Counties	109,000 to 635,000	+0.011°F
Large Counties	664 to 8,710	+0.026°F

Temperature trends were calculated for the seven climatic divisions from *Climatological Data,* for the seven stations included in the World Weather Data, and for the 33 stations from the National Historic Climate Network. The 80-year average temperature trends for California are:

Figure 1
TEMPERATURE TRENDS IN CALIFORNIA, 1909-1989

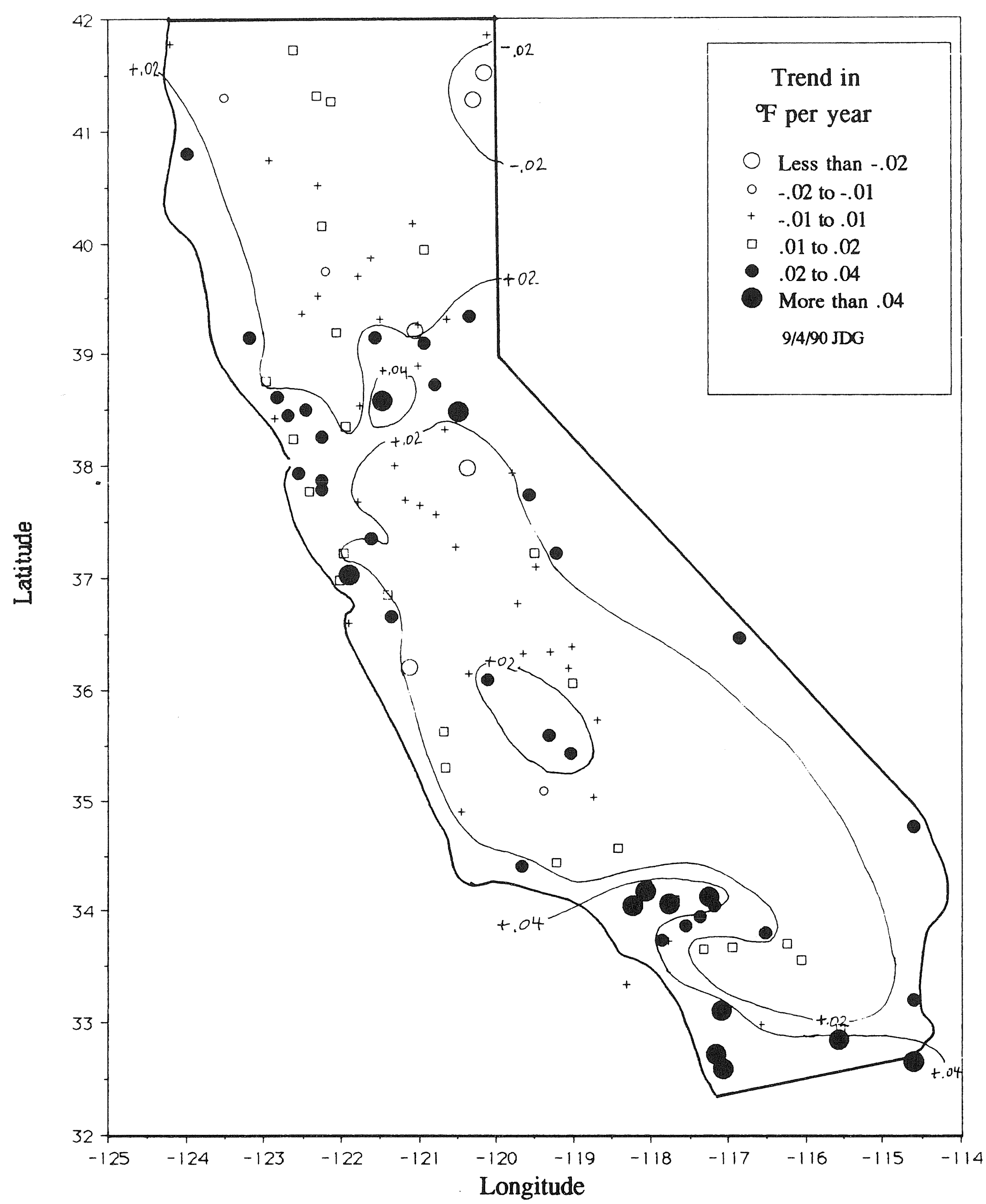
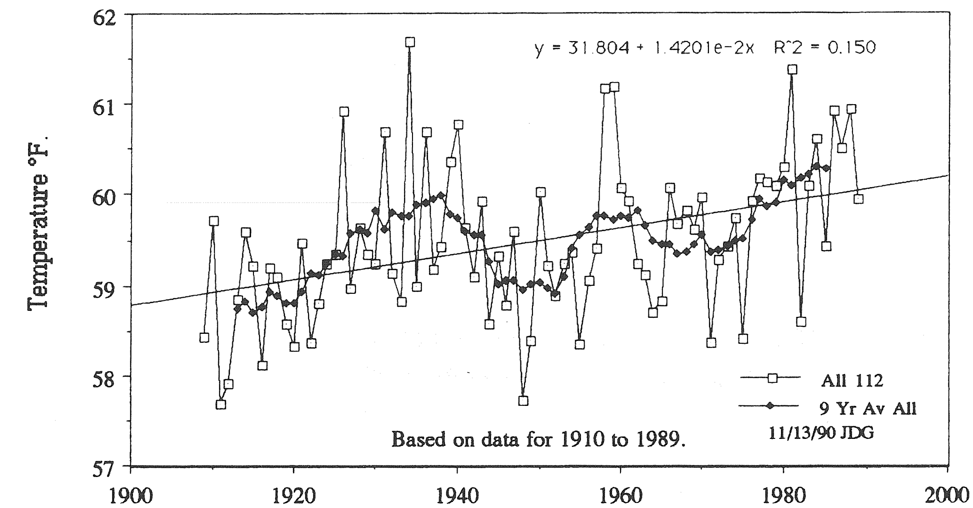


Figure 2
AVERAGE ANNUAL TEMPERATURE FOR 112 CALIFORNIA STATIONS



Data Set	Number of Stations	°F per Year
All Stations	112	0.014
Small Counties	28	0.005
Mid-size Counties	50	0.011
Large Counties	34	0.026
North Coast 1	14	0.018
Sacramento Valley 2	26	0.006
Northeastern Interior 3	3	–0.004
Central Coast 4	14	0.015
San Joaquin Valley 5	24	0.007
South Coast 6	21	0.027
Southeastern Desert 7	10	0.026
National Historic Climatic Network	33	0.014
World Weather Records	7	0.032

The World Weather Records dataset has a strong urban bias in the California portion, as shown by the +0.032°F per year trend. This is larger than the trend for the large counties. The National Historic Climatic Network was an attempt to correct deficiencies in the World dataset by eliminating urban bias. The National Network has a 1910 to 1989 trend of +0.014, the same as the average of all 112 records.

Most California temperature records show a heating trend for 1910 to 1989, partly due to the choice of starting and ending dates of the study period. This study is based on an 80-year period since the method of calculating mean daily temperature (as the average of daily maximum and minimum) was uniform for all stations in the United States. Until about 1906, daily means for some stations were calculated as the mean of several daily fixed time observations. Starting this study with a base period before 1910 would further reduce the number of stations available for comparison. Only three stations in California have temperature records extending back to 1850: San Diego, San Francisco, and Sacramento. The first reported temperature record for California was at Fort Ross, with data from 1837 to 1840 (Chernykh 1841).

The main reason for the heating trend in California temperature records is urban heat island or thermal pollution associated with a large population where temperature is measured. The population of California has increased by a factor of 12 — from 2.4 million to 29 million people during the 80 years of this study.

Not all regions of California have shared this growth. For example, the Glenn County population has grown from 7,000 to 24,000, and the 80-year temperature trend is –0.002. In Modoc County, the population has grown from 6,200 to 9,500, and the temperature trend has averaged –0.010 for three of its communities: Alturas, Fort Bidwell, and Cedarville.

Of the 112 California temperature stations, 20 show a cooling trend. Declining temperature trends are not in urban centers, but in small towns and rural areas. Figure 1 shows the annual temperature trend plotted for each station. Regions with 0.02°F increases are generally the urban centers of San Francisco/Sacramento and San Diego/Los Angeles. However, urban centers are not the only regions with increasing temperature trends. Air temperature in coastal California was highly correlated with sea surface temperature. In these areas, the trend of increasing air temperature corresponds to a period of declining cold water upwelling near the shore of the eastern North Pacific Ocean, starting about 1975.

Beginning in 1947, data on sea surface temperature in the North Pacific Ocean are plentiful. Sea surface temperature studies from offshore 5° grid points reported here cover 43 years, 1947 to 1989. These grid points are in the eastern North Pacific Ocean, north of latitude 30°N and east of longitude 160°W. Sea water temperature data for ocean grid points, supplied by Cayan (1990), are plotted on Figure 3, along with trends at adjacent near-shore stations. The shore and near-shore stations have a notable heating trend, contrasting sharply with the trend of –0.0145°F at the 48 mid-ocean 5° grid points plotted on Figure 4. The SST reflects part of a roughly 20-year cyclic variation, as shown on Figures 5 and 6. This cyclic variation in SST was described by Newell (1989), who attributes it to the solar magnetic cycle.

The trend in upwelling at three ocean stations off the West Coast is shown on Figure 7 (from Bakun 1986). Bakun's upwelling index, like the SST data of Figures 5 and 6, is represented here as a 9-year running average. A decline in cold water upwelling near the shore starts about 1975, and the SST trend responded by not declining in the 1980s as would be expected from a well defined 20-year cyclic pattern.

Average annual air temperature at California stations was correlated with average annual sea surface temperature at one ocean grid point centered at latitude 35°N and longitude 125°W. The correlation (R^2) is highest (0.5) at coastal stations and is near zero at the interior desert stations, as shown on Figure 8.

When the National Climate Program Act was passed 10 years ago, it was hoped that the number of temperature measuring stations for California would increase, but the reality is that the number continues to decline (Figure 9). The federal response to the temperature measurement problem has been to eliminate stations — some with as much as 100 years of record — and spend millions on "greenhouse" studies.

Figure 3
TRENDS IN SEA SURFACE TEMPERATURE AND NEAR-SHORE TEMPERATURE

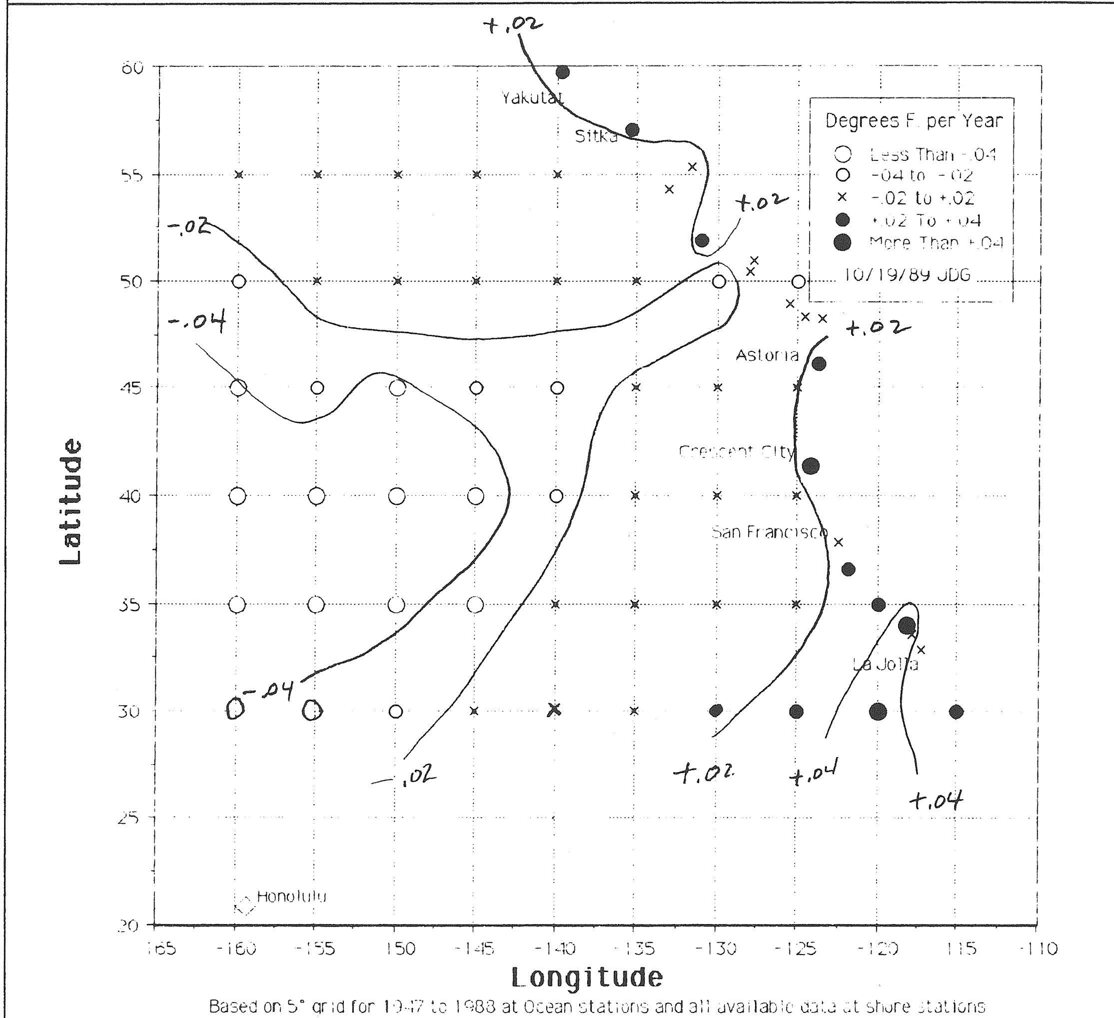


Figure 4
TREND IN SEA SURFACE TEMPERATURE, EASTERN NORTH PACIFIC OCEAN

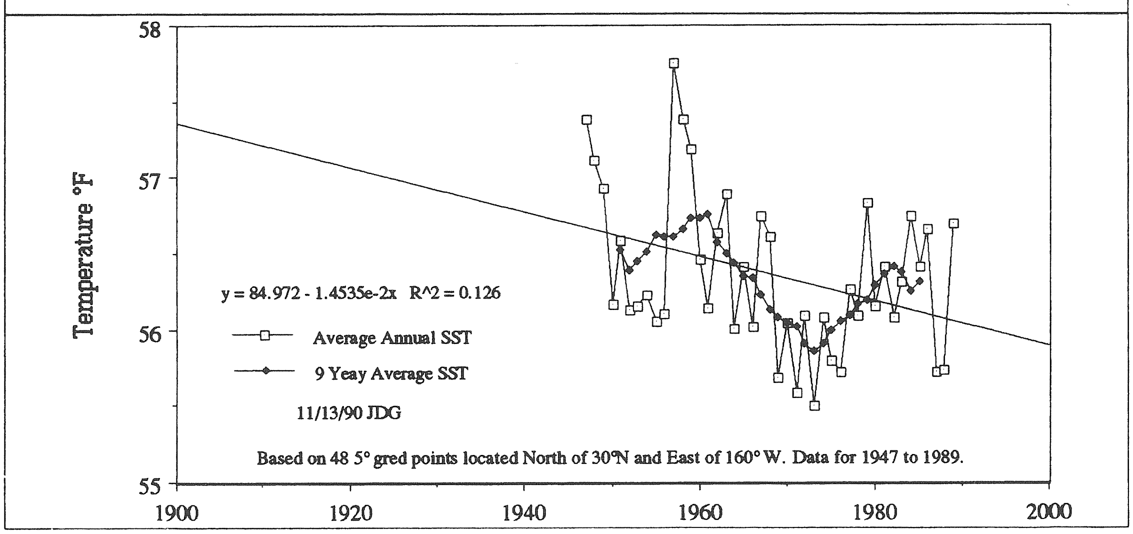


Figure 5
SEA SURFACE TEMPERATURE AT OFFSHORE STATIONS
9-Year Running Average

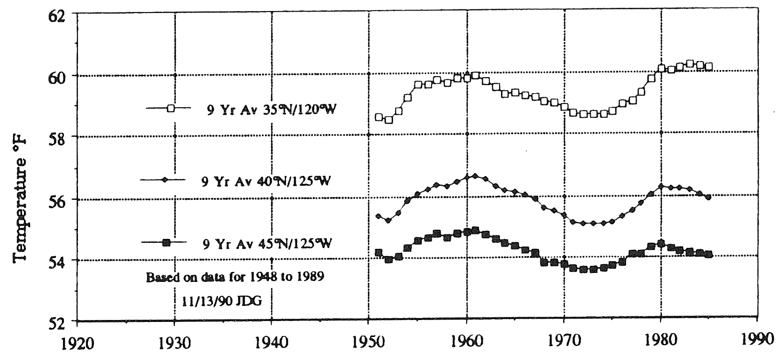


Figure 6
SEA SURFACE TEMPERATURE AT NEAR-SHORE STATIONS
9-Year Running Average

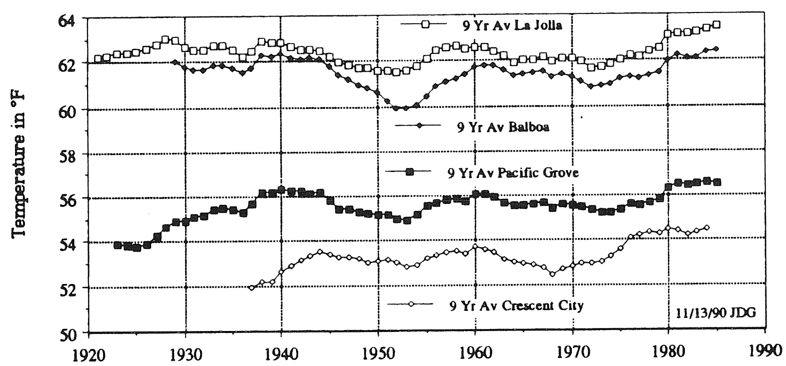


Figure 7
BAKUN'S UPWELLING INDEX
9-Year Running Average

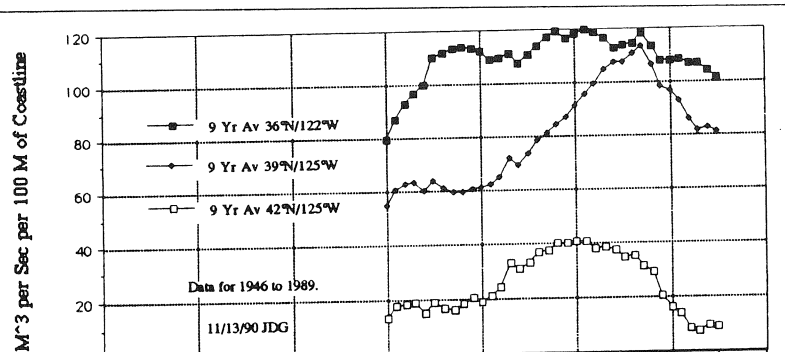


Figure 8
CORRELATION BETWEEN AIR TEMPERATURE AND SEA SURFACE TEMPERATURE

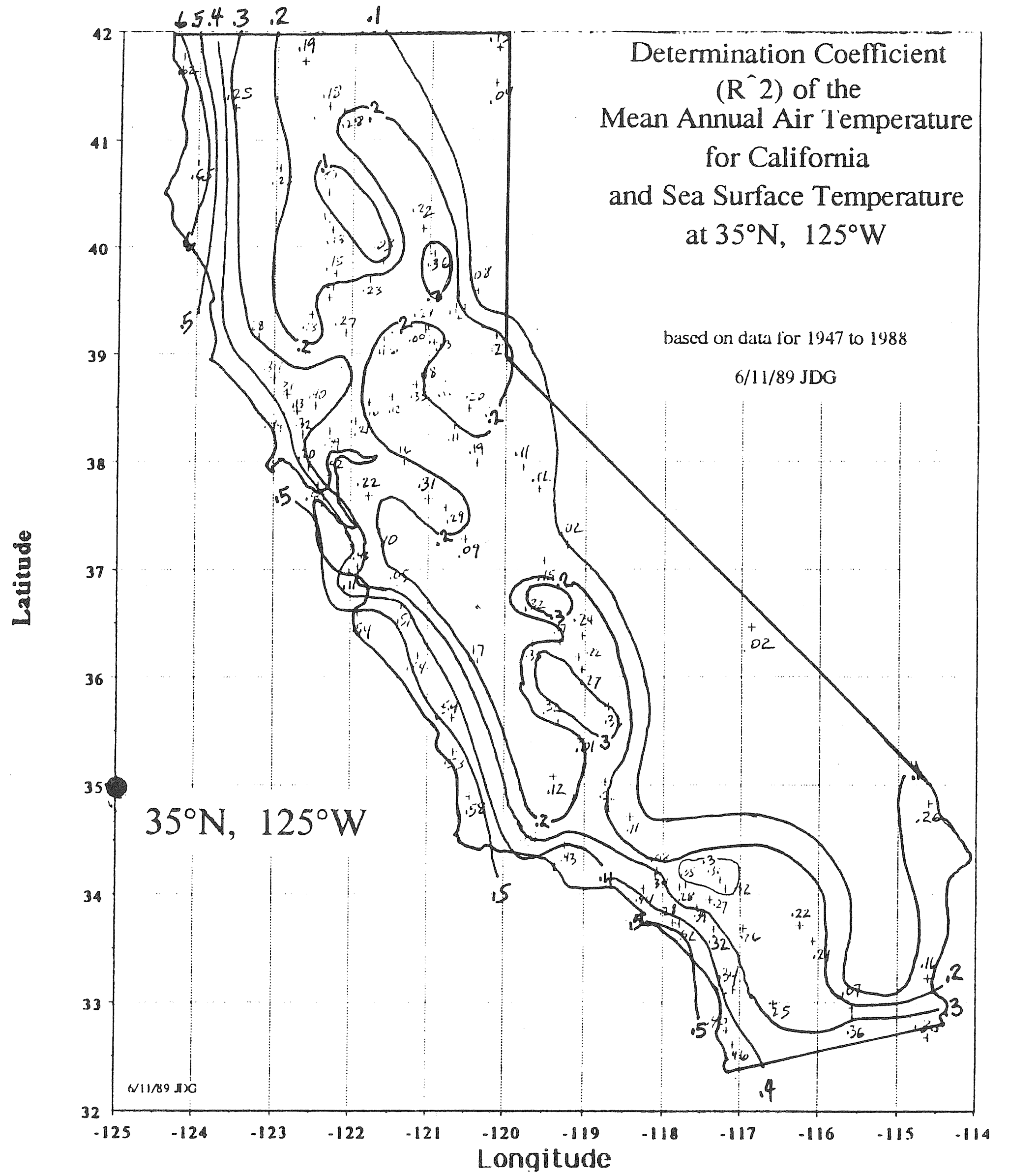
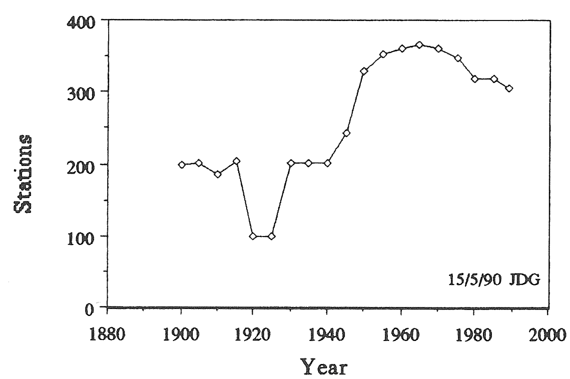


Figure 9
NUMBER OF TEMPERATURE STATIONS IN CALIFORNIA



No of temperature records published in Climatological Data.

Forces acting on air temperature trends, such as the influence of sea surface temperature and urban waste heat, are masked by averaging all records together. Thermometers exposed over blacktop runways or roads may not be compatible with data collected over sodded ground. The traditional "cotton region shelter" has louvers that protect thermometers from the sun, but nothing protects them from long-wave radiation from hot pavement. With shelters over grass, the long-wave radiation may not have been a problem.

We need more answers about the spectral distribution of radiation from the urban environment and how our instrument shelters and thermometers respond to it. It is too early to attribute heating trends to a "greenhouse effect".

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