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PACIFIC OCEAN AIR INTERACTIONS: CALIFORNIA SEASONAL AIR TEMPERATURES VERSUS OCEAN TEMPERATURES

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Over the past several years, numerous articles have been written on ocean-air interactions. A variety of data sets as well as a number of different statistical methods have been used to identify the relationships that exist between the state of the Pacific Ocean sea surface temperature (SST) field and the atmosphere over North America (e.g., Fritz 1982; Yarnal and Diaz 1986; Nicholls 1988; Lau and Nath 1990). For example, Yarnal and Diaz (1986) and Namias and Cayan (1981) have studied the statistical relationships that exist between the Pacific Ocean temperature field and winter precipitation occurrence in the western United States. Namias and Cayan (1981) found that the summer Pacific Ocean temperature anomalies were related to the strength of the fall Aleutian Low pressure system. Likewise, Fritz (1985) and Pyke (1972) have stated that the nature of the Aleutian Low is related to the characteristics of the Pacific Ocean temperatures. Specifically, they related the strength and position of the low to water conditions.

Our study presents an extension of these research projects and examines the relationships between fall, winter, spring, and summer average surface air temperatures in California and fall, winter, spring, and summer average Equatorial and northern Pacific Ocean temperatures. Few ocean-air interaction studies have concentrated solely on the entire state of California (Schonher and Nicholson 1989). However, several researchers have examined the relationships between either coastal California air temperatures or regional precipitation amounts (e.g., Yarnal and Diaz 1986, Namias 1988, Sheeley and Dorman 1979, Hannes 1974). Furthermore, Ropelewski and Halpert (1986) have examined the

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association between North American monthly mean air temperatures and El Niño/Southern Oscillation episodes. This report differs from the previously mentioned research articles in several aspects. The major differences include the time period of analysis, the statistical technique employed, and the individual station locations used in the analysis. This research paper is not restricted to the study of coastal sites, but employs a variety of California weather sampling sites.

Study Area

We selected seven ocean locations to represent the northeastern Pacific Ocean (Table 1). Three areas were chosen to represent the El Niño region along the Equator (Figure 1). Sea level atmospheric pressure data for the Southern Oscillation/El Niño Index (Bigg 1990) for the stations at Darwin (Australia) and Tahiti were included in our study. We used sixteen sites with a diversity of physical characteristics throughout California.

Table 1.
Northern Pacific Ocean Sea Surface Temperature Locations

50° N, 155° W	35° N, 155° W
50° N, 145° W	35° N, 145° W
50° N, 135° W	35° N, 135° W
	35° N, 125° W

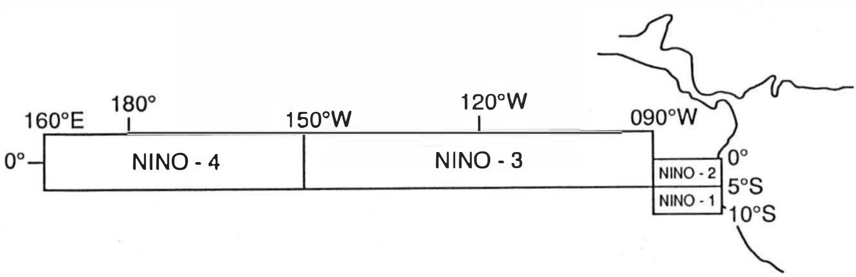

Figure 1. El Niño Areas as Defined by Kousky and Halpert (*Journal of Climate*, Vol. 4, No. 1, January 1991)

Data and Methods

Nineteen years of data were used (1970-1989). Since data from the Equatorial areas were not available prior to 1970, the length of the time period for our project was limited. We obtained the Equatorial sea surface temperature data and sea level pressure data from Dr. Kousky (refer to *Journal of Climate* 1991, for a description of the data). North Pacific sea surface temperatures were acquired from Mr. J. Goodridge and they represent averages calculated at Scripps Institute of Oceanography for 5° areas of latitude and longitude. The average surface air temperatures were taken from *Climatological Data Annual Summary: California (NOAA)*. The values were then averaged by season. For example summer refers to the average air temperatures for the months of June, July, and August; fall represents September, October, and November. Using a standard computer program, ocean temperatures, air temperatures, and sea level pressures were correlated with one another for each season (Pearson's r). The computer program also calculated the significance level of each association using the Student's t distribution. Caution is suggested in the use of the significance

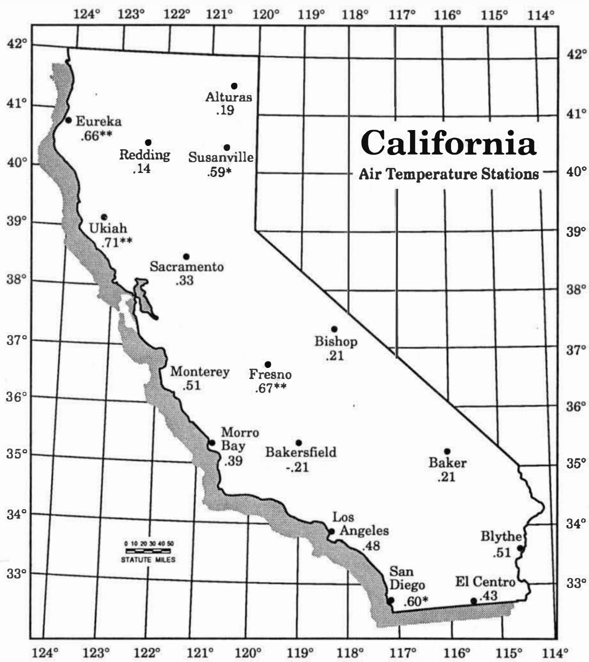

Figure 2. Correlation Between Spring Ocean Temperatures at 50°N 145°W and Spring California Air Temperatures [Significance levels for all Figures: * = 0.01; ** = 0.001]

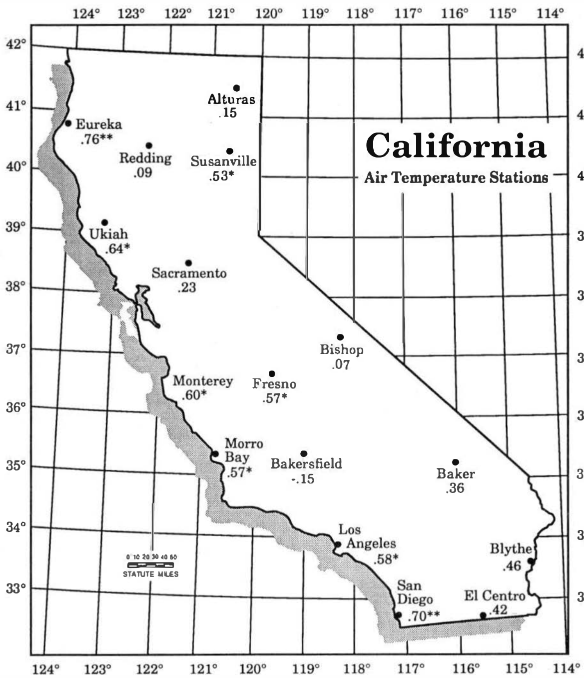

Figure 3. Correlation Between Spring Ocean Temperatures at 35°N 125°W and Spring California Air Temperatures

level when using a large data matrix; some statistical associations may occur by chance alone (Norusis 1986).

Results

The significant correlations will be presented in the following five subsections. The spring data will be given first, followed by the summer data, fall data, winter data, and lastly the significant correlations formed between sea level pressure measured at Tahiti and Darwin and California air temperatures.

Spring California air temperatures vs. spring SSTs. Figures 2 and 3 show the correlations produced between sea surface temperatures at 50°N, 145°W and 35°N, and 125°W and spring California air temperatures. Both figures indicate that Eureka, Ukiah, Fresno, San Diego, and Susanville were significantly correlated with water temperatures at both 50°N 145°W, and 35°N, 125°W. Walsh and Richman (1981) also found that San Diego was significantly correlated with northern Pacifico cean temperatures in all seasons. Furthermore, Eureka, Ukiah, and Fresno have also been significantly correlated with high latitude ocean temperatures sampled at 50°N, 155°W (not shown). None of the California sites during the spring were significantlly correlated with water temperatures in the El Niño areas.

Summer California air temperatures vs. summer SSTs. During the northern hemispheric summer, the largest number of California sites were significantly correlated with Equatorial water temperatures in the El Niño areas (Figure 4). Coastal sites of Eureka (positive), Ukiah (negative), and Morro Bay (positive) and interior sites of Susanville (negative) and Bishop (negative) were related to the ocean temperatures sampled off of the coast of South America. Further- more, Sacramento was significantly correlated (negative) with El Niño areas 3 and 4.

Water temperatures measured at 35°N, 135°W were linked with air temperatures gathered at Sacramento and the interior cities of Alturas and Susanville (Figure 5). This finding differs from Walsh and Richman's study of 1981. They found that the northeast portion of California did not significantly correlate with their northern Pacific ocean temperature anomalies. Their summer period included the months of May, June, and July, wheras our study considers the summer months of June, July, and August. The sea surface temperatures taken at 35°N, 125°W were significantlly correlated with air temperatures measured at Eureka, Monterey, and San Diego. Apparently, these coastal air temperatures had been modified by the adjacent water. The coastal cities of San Diego and Los Angeles were strongly related (positively) to water temperatures sampled at 50°N, 155°W. Thus, one can conclude that during the summer season, a complex pattern of correlations existed between California air temperatures,

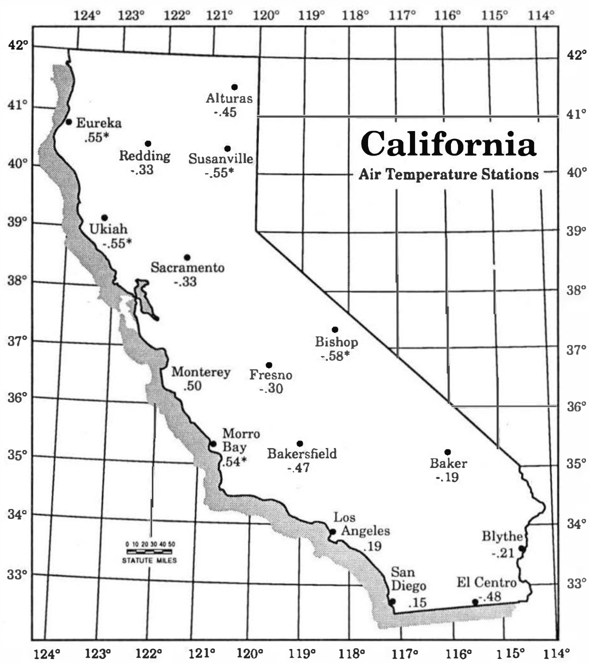

Figure 4. Correlation Between Winter (S.H.) Ocean Temperatures in the El Niño 1 & 2 Area and Summer California Air Temperatures

especially the coastal cities, and water temperatures sampled along the Equator, in the subtropics, and at high latitudes.

Fall California air temperatures vs. fall SSTs. During the northern hemispheric fall, the coastal sites of Eureka, Monterey, and Los Angeles were strongly related (positively) to ocean temperatures in El Niño area 1 & 2. Eureka and Fresno were found significantly correlated (positively) with water temperatures taken at 50°N, 135°W. An inverse relationship occurred between water temperatures recorded at 35°N, 155°W and the interior cities of Fresno, Bishop, Susanville, and Alturas (Figure 6). Once again, we found that air temperatures sampled at a few sites were strongly associated with ocean temperatures measured at both 35°N and 50°N latitude. This strong correlation agrees with the findings of both Namias (1978) and Hoerling, et al. (1992) that extratropical SST anomalies have important feed-backs with the seasonal climate of the west coast of North America. Namias, et al. (1988) have also shown that certain specific areas of the Pacific Ocean have important effects on the atmospheric flow structure and storm tracks. This is possibly why the water temperatures sampled at both 50°N, 155°W and 50°N, 145°W were not strongly related to California airtemperatures but were only associated with the nearby water temperatures sampled at 50°N, 135°W.

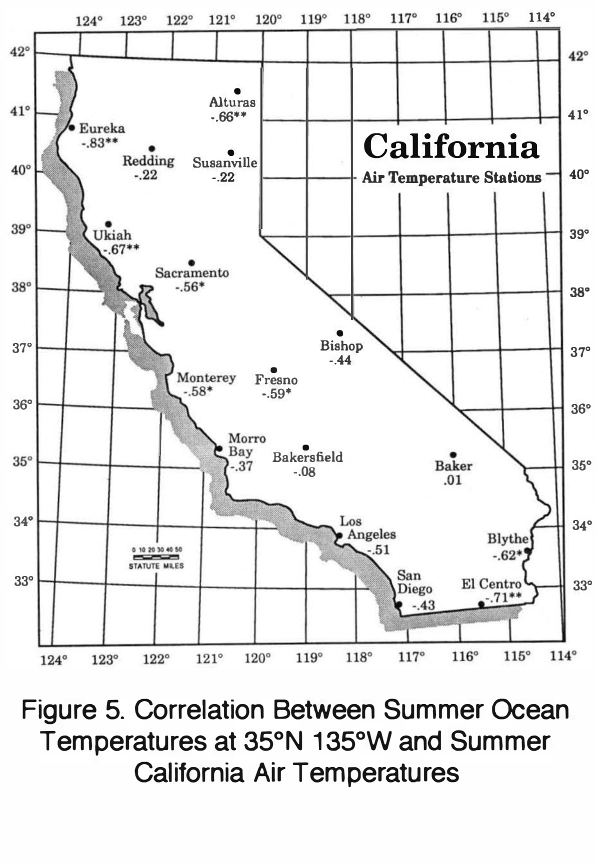

Figure 5. Correlation Between Summer Ocean Temperatures at 35°N 135°W and Summer California Air Temperatures

California winter air temperatures vs. winter SSTs. El Centro, Blythe, Monterey, Ukiah, and Eureka were postively correlated with SSTs collected at 35°N, 125°W (Figure 7) but were negatively correlated with ocean temperatures taken at 35°N, 145°W (Figure 8), and 35°N, 155°W. This interesting situation was probably related to the difference in year-to-year variations among these three ocean locations. From an examination of the raw data, the year-to-year temperature changes sampled at 35°N, 125°W were definitely out of phase with the other two sites. This situation underscores the changeable nature of adjacent pools of water that exist in the ocean.

The coastal cities of Eureka, Ukiah, and Monterey had their respective winter temperatures significantly correlated with winter water temperatures taken at 50°N, 135°W. This finding agrees with the conclusions of Namias (1978) who showed that Eureka's air temperatures were significantly correlated with the sea surface temperatures measured at 40°N, 125°W. Likewise Granger (1988) concluded that winter northern California coastal climate anomalies had been in phase with extratropical teleconnections. Eureka's winter air temperatures were also strongly associated with water temperatures gathered along the Equator in El Niño area #4. Again, Yarnal and Diaz (1986) indicated that coastal northern Californias' climate was significantly correlated with both the warm and cold phase of the Southern Oscillation. Thus,

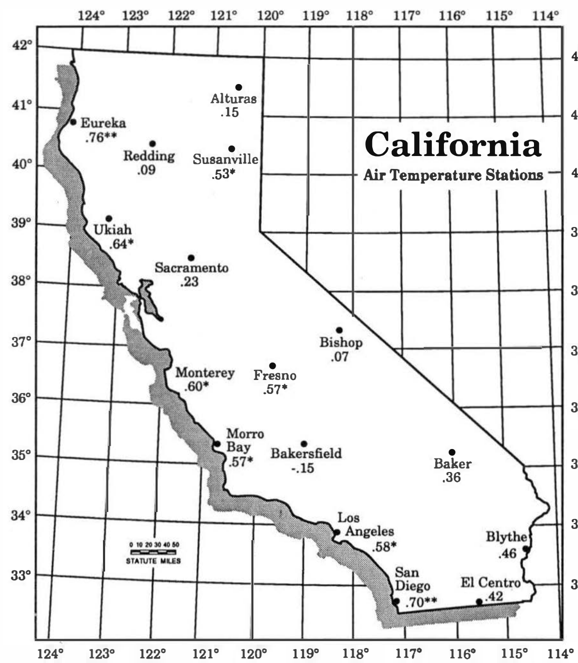

Figure 6. Correlation Between Fall Ocean Temperatures at 35°N 155°W and Fall California Air Temperatures

Eureka's air temperatures response to the tropical water temp- erature changes likely represents some form of teleconnection.

California air temperatures vs. sea level pressure. The sea level pressure values sampled at both Darwin and Tahiti are used in the calculation of the Southern Oscillation Index (Bigg 1990). This index has been used to predict the onset of El Niño events (Allen, et al. 1991). It was interesting to see if any California sites were sensitive to the components of this important predictive index. Three California locations were significantly correlated to the index components. Darwin was positively correlated during the summer with Eureka, while Ukiah was positively correlated with Darwin during the spring, and negatively correlated during the summer season. Tahiti's sea level pressure was significantly correlated with air temperatures collected at both Los Angeles (summer; negative) and Eureka (winter; negative). Again, this association of Eureka's air temperatures with sea level atmospheric pressure measured at both Tahiti and Darwin supports the research results of Yarnal and Diaz (1986) that the Southern Oscillation does have an impact on coastal northern California air temperatures. Furthermore, our research substantiates the conclusions drawn by Ropelewski and Halpert (1986) using harmonic analysis of monthly

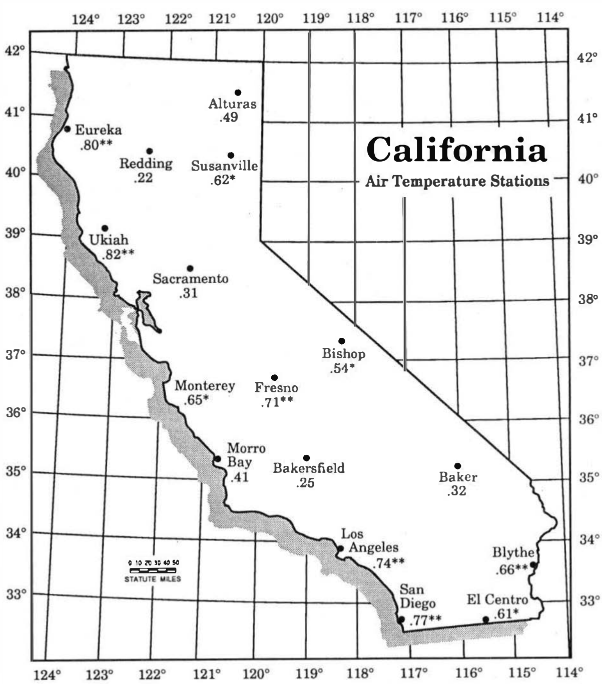

Figure 7. Correlation Between Winter Ocean Temperatures at 35°N 125°W and Winter California Air Temperatures

North American temperatures. They found that North American air temperatures were related to El Niño / Southern Oscillation events but in a complex fashion.

Conclusions

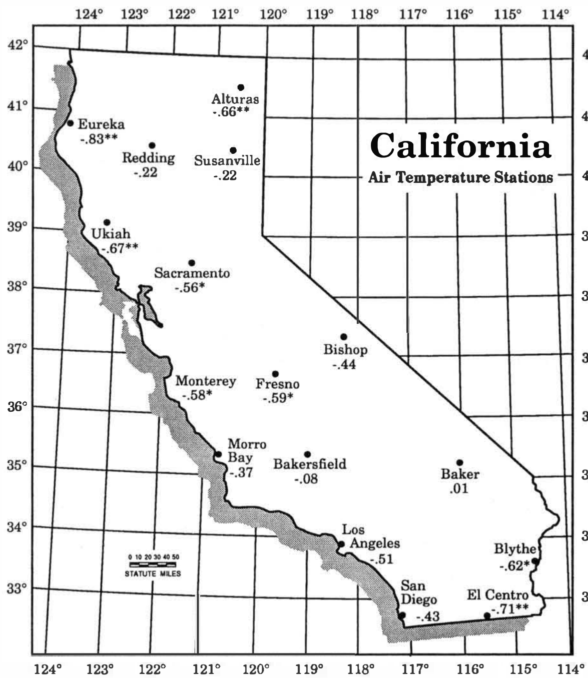

Figure 8. correlation Between Winter Ocean Temperatures at 35°N 145°W and Winter California Air Temperatures

Our research project has shown that seasonal air temperatures recorded throughout California were related to water temperatures sampled along the Equator, the subtropics (30°N) and at high latitudes (50°N). Coastal cities such as Eureka were significantly correlated to SSTs at the Equator (e.g., Figure 4), the subtropics (e.g., Figure 3), and at high latitudes (e.g., Figure 2). During the spring season, no California cities were significantly correlated to water temperatures taken in the El Niño areas, while during the other three seasons, some California locations had been significantly correlated with the El Niño water temperatures. Possibly more California sites would be sensitive to tropical ocean temperatures if a seasonal lag was used. In Granger's 1988 study using a seasonal lag, coastal sites and water temperature anomalies were interrelated. Lastly, a few California locations were significantly correlated with sea level atmospheric pressure taken at either Tahiti or Darwin. This project also updates the findings of earlier studies such as Walsh and Richman (1981) who covered the period from 1947 to 1977 and Yarnal and Diaz (1986) who used only coastal data from 1933 to 1977. Also this analysis employed more stations in California that the studies conducted by either Granger (1988) or Walsh and Richman (1981). Ocean temperatures sampled along 35°N latitude recorded more significant correlations with the air temperatures sites than water temperatures taken at either 50°N latitude or along the Equator. This seems logical since the State of California extends in a north-south direction from about 33°N to 42°N latitude. The adjacent ocean and the atmospheric westerlies should influence Californias' climate to some extent. These basic climatic influences have been described by Bailey (1966) many years ago. Future research should examine a variety of SST lags with California climatic data and employ a denser ocean temperature grid to study the link between California's climate and the ocean. Once this link is established, then possibly climatic forecasts will improve.

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