# 8.5 June Gloom and Heavy Fogs: Oceanic Influences on Bummer California Summers

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## 1. Introduction

The mildness of coastal southern California's climate is a result of the Pacific Ocean and especially the adjacent cool California Current. During the summer, beach ocean temperatures remain in the low to mid-60s Fahrenheit from Santa Barbara to Los Angeles, and only slightly higher, into the high 60s moving down towards San Diego. The sea breeze off these cool waters influences coastal air temperatures, modifying the heating of land surfaces. On the other hand, inland coastal valleys often have scorching summer temperatures under cloudless skies and subsidence inversions. This leads to daily migrations of southlanders from the hot concrete urban jungles to find relief at the beaches. However, since 1998, these sun worshippers have been greeted more often with low stratus and fog and water temperatures too chilly for bathing. Why the sudden change in coastal weather? What causes some years to be warmer and sunnier at the beaches than other years? This study looks at the possible causes of season-long June Gloom (or Bummer Summer).

## 2. Earlier Studies

Over the past several years, there have been numerous articles written on air-sea interactions. Several datasets and statistical methods have been used to identify relationships between the sea surface temperatures (SSTs) of the Pacific Ocean and the atmosphere over North America. Besides relationships to precipitation and other hydrological parameters, several recent studies have related tropical and extratropical SSTs to temperatures along the west coast, including California. Namias (1978) found that extratropical SST anomalies have important feedback mechanisms with seasonal climate of the North American west coast. These feedbacks included influences on the strength and position of the Aleutian Low (Namias and Cayan 1981) and the general circulation patterns (Lau and Nath 1990), including atmospheric flow and storm tracks (Namias, et al. 1988). More numerous studies concentrate on the relationships between tropical Pacific SSTs and west coast climate. Pyke (1972) and Fritz (1982) show the relationships between tropical Pacific SSTs and the Aleutian Low characteristics. Angell and Korshover (1981) compared equatorial eastern Pacific SSTs to U.S. surface temperatures, while Ropelewski and Halpert (1986) and Yarnal and Diaz (1986) related North American temperature patterns to the phases of the El Niño/Southern Oscillation (ENSO). The Angell and Korshover found only weak relation between SSTs and west coast temperatures. Ropelewski and Halpert's study showed that North American monthly temperatures were related to ENSO, but in a complex manner. Yarnal and Diaz, using coastal data from 1933 to 1977, found that ENSO extreme values did correlate with some coastal California stations. Similarly, Walsh and Richman (1981), Granger (1988) and Hannes and Hannes (1993) found North Pacific SSTs significantly correlated to coastal California seasonal temperatures. Granger used a seasonal lag between ocean temperatures and coastal air temperatures, while the other two studies used concurrent seasonal data. Hannes and Hannes (1993) used 7 North Pacific SST locations between 35ºN, 155ºW, to 50ºN, 135ºW, as well as El Niño areas: Niño-1, Niño-2, Niño-3 and Niño-4 SSTs related to 16 California stations' seasonal temperatures. These stations included coastal and inland locations throughout the state. For most California locations, SSTs at 35ºN locations correlated stronger with air temperatures than 50ºN locations and tropical locations. Highest correlations for the southern California coastal stations were between SSTs

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at 35ºN, 125ºW in winter, while in summer San Diego and Los Angeles air temperatures were strongly (positively) related to SSTs at 50ºN, 155ºW, but negatively related to those at 35ºN, 125ºW. Here it is evident that single ocean locations do not explain same season air temperatures in southern California. Unfortunately, the authors did not apply lags to the ocean data. While extratropical climate response to SSTs seems to be largely restricted to the cold season (Zhang, et al. 1997; Latif and Barnett 1996), the present study concentrates on air-sea interactions impacting the summer season.

## 3. Data and Methods


Fig. 1. California climate divisions. Study concentrates on division 6 (source: NCDC).

In the present study, the authors use Pacific Ocean SSTs and atmospheric circulation patterns, both in the tropics and extratropical latitudes, to explain summer air temperatures along the southern California coast. For these preliminary investigations, the online Climate Diagnostics Center (CDC) Correlations web page was used to test relationships (2002a). Most correlations compared the seasonal surface air temperatures for the coastal southern California climatic division (fig. 1), for the months June to August, with various Pacific oceanic and atmospheric indices for the years 1948 to 2001 (CDC 2002b). Atmospheric and oceanic indices investigated in this study include: SOI (Southern Oscillation Index); Niño-1, Niño-2, Niño-1&2, Niño-3, Niño-4, Niño-3.4 SSTs; PDO; PNA; NP; Pacific Warm Pool Index; E. Pacific Oscillation; Arctic Oscillation; W. Pacific Index; QBO (quasi-biennial oscillation); and the NAO (N. Atlantic Oscillation). Finding indices that explain variability in southern California coastal summer temperatures may be useful in long range forecasting.

A related study has shown that coastal temperatures influence the frequencies of dense fog (LaDochy, 2002). Pacific SSTs again figure prominently in the frequency of coastal dense fog. However, along the Los Angeles coast, urban influences seem to also play important roles. Dense fog data for the two coastal Los Angeles airports, LAX and LGB (fig. 2) from 1950 to 2001 reveal recent PDO and ENSO patterns. Los Angeles Civic Center temperatures and particulate air pollution levels are also tested for relationships.


Fig. 2. Study area showing LA airports along with average number of fog days at southern California locations.

## 4. Results

As mentioned earlier, ENSO variables and PDO have both been linked to North American weather. Using the CDC Correlation web page, the authors ran linear correlations between the mean June-August summer temperatures for coastal southern California (California climatic division 6) at progressive leads of 0 to 6 months. Correlations with the SOI and Niño-1 & 2, 3, 4 and 3.4 at different leads did not show consistent or strong relationships with summer coastal temperatures. However, PDO values were fairly strongly related to division 6 temperatures, especially April-June (2 month lead), yielding a maximum r of +.555 (fig. 3). Correlations for individual months were lower.

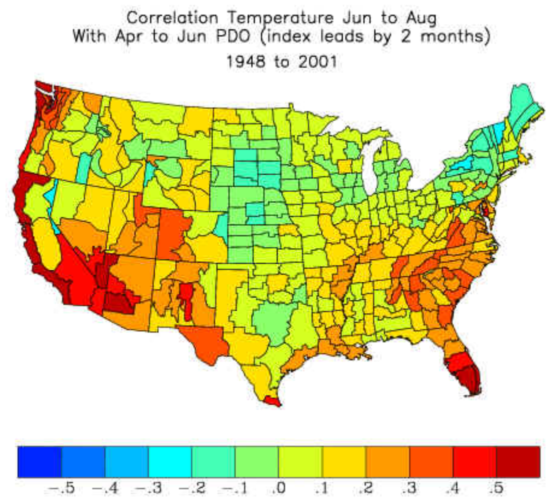


Fig. 3. Correlations between summer air temperatures and April-June PDO values by climatic divisions (source: CDC).

June coastal temperatures had a maximum r = +.503 with May PDO values, while July maximum r was +.277 with June PDOs with slightly lower r values at leads of 2 and 5 months (May and February PDOs). August temperatures had a high r of +.450 with April PDOs (4 month lead), with lower r values at 5 months, 3 than 2, in that order. The Pacific Warm Pool Index also showed similar positive correlations, with r = +.418 between summer temperatures and Feb.-Apr. WPI values (4 month lead), shown in fig. 4. Correlation scores were fairly similar for all coastal California divisions for leads of 1 to 4 months. The North Pacific Index maximum r was -.414 with division 6 temperatures for a 3-month lead (Mar.-May,

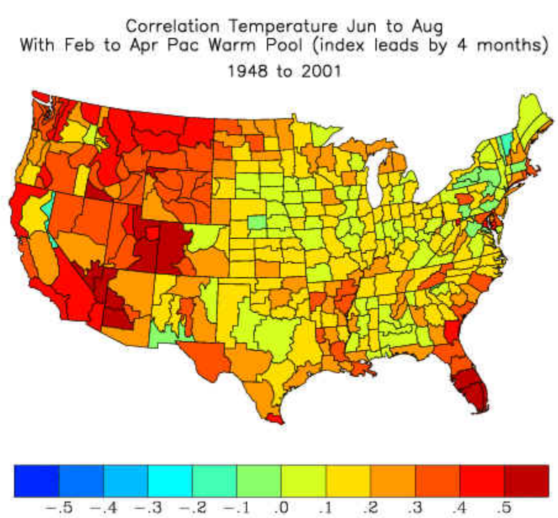


Fig. 4. Same as fig. 3, except for April-June Pacific WPI (source: CDC).

fig. 5). Fig. 6 shows the maximum correlation for PNA values, with r = +.391 at a 5 month lead (Jan.-Mar.). Indices that did not show as high relationships, and often with quite mixed results included: West Pacific Index, the Arctic Oscillation, the Tropical Pacific EOF Index, and non-Pacific variables, the QBO (Quasi-biennial oscillation) and the Solar Cycle Flux. But what do these results mean?

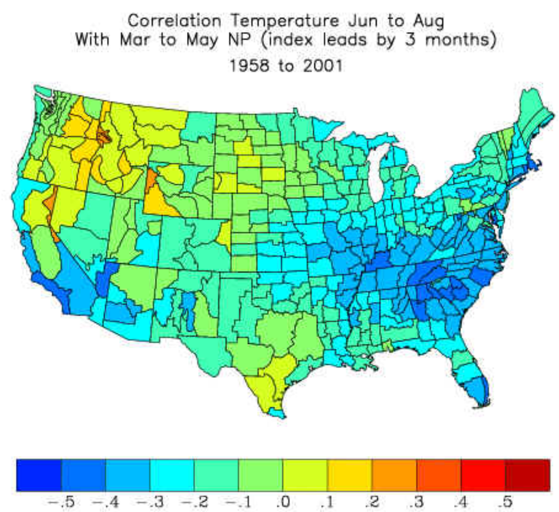


Fig. 5. Same as fig. 3, except for March-May NP Index (source: CDC).

It is not surprising that PDO explains summer temperatures. As stated above, North Pacific SSTs are better predictors of west coast climate than tropical SSTs. In a recent study, Lau, et al. (2002) found that while the tropical Pacific was largely responsible for fall and winter west coast climate, the North Pacific SSTs related best for spring and summer climate along the west coast. Also, because of the PDO's strong tendency for multi-season and multi-year persistence, it has proven to be an important input in long-range forecasting (Mantua 2002). Even ENSO teleconnections with North American climate has been shown to be strongly dependent on the phase of the PDO, so that these relationships are only valid during years when ENSO and PDO extremes are in phase (Gershunov, et al. 1999). The strong negative correlations with the NP Index can be related to the fact that this mode of North Pacific SSTs differs from the ENSO pattern and along with PDO, relates to summer North American climate patterns. The negative mode of NP includes cooler SSTs along the west coast, stronger northerly flow of the California Current and greater upwelling along the coast. This pattern occurred from 1962-65, when there was strong positive NP and a cool (negative) phase of PDO (Nigam, et al. 1999). The strong positive correlation with the Warm Pool Index may seem contradictory since tropical indices such as SOI only showed a weaker connection. However, the WPI is the first EOF of Pacific SSTs (CDC 2002b), measured across the western portion of the equatorial and tropical Pacific from 60ºE to 170ºE, a large section of the Pacific heat engine. Together, the PDO, WP, NP and PNA indices cover the SST patterns and their influences on pressure patterns for the northern Pacific Ocean. The results of this study show that these indices also show promise in predicting summer weather along southern California's coast.

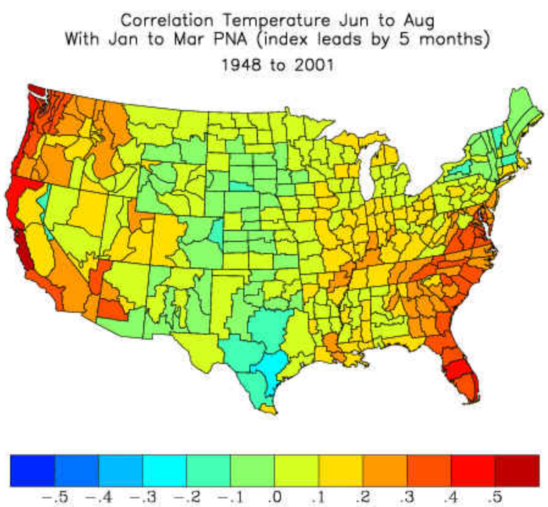


Fig. 6. Same as fig. 3, except for January-March PNA Index (source: CDC).

Dense fog along the southern California coast have been related to SOI and PDO values for the Los Angeles coastal area by Witiw, et al. (2002). They found that colder water temperatures associated with negative PDO and positive SOI values led to higher incidences of dense fogs, although the SOI contribution was small. The present authors also looked at dense fog for the Los Angeles coastal region, using LAX and LGB airports as well as downtown L.A. (LAC). Fig. 7 shows the annual number of days with dense fog for the period 1950-2000. The overall pattern indicates a gradual decline in fog frequencies. The decreases in fog may be related to the rising urban heat island effect and the decrease in particulate pollutants (LaDochy 2002). Sharp peaks and valleys also appear in the record. For the most part, peaks correspond mainly to La Niña years, while minima reflect Type 1 El Niño years. Since 1998, dense fog frequencies have been climbing. Although the record is too short, PDO values show stronger relationship to fog than ENSO (Witiw, et al. 2002).

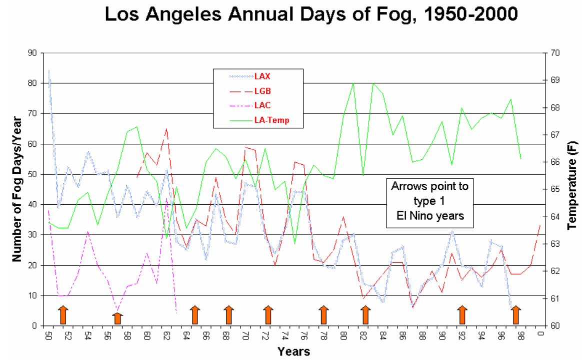


Fig. 7. Annual days of dense fog at LAX, LGB, LAC along with downtown LA temperatures.

## 5. Conclusion

This study shows that summer temperatures along coastal southern California are affected by SSTs, particularly those in the extratropical Pacific. The correlations also indicate that spring Pacific Ocean indices may be a good predictor for summer conditions. In particular, the PDO, Pacific Warm Pool, NP and PNA indices appear to have useful relationships for making predictions. June Gloom, cool temperatures and foggy weather, has dominated summers along the southland coasts of California since 1998. The authors contend long-range forecasts of these unwelcome conditions can be made with sufficient confidence to make surfers don their wet suits.

## 6. Acknowledgements

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