P1.23 CENTRAL CALIFORNIA: OPPOSING TEMPERATURE TRENDS VALLEY VS. MOUNTAINS

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1. INTRODUCTION

Since the late 19th century, significant changes have occurred in the San Joaquin Valley of Central California, most notably the conversion of over 3 million acres of what was essentially desert into productive farmland. The conversion was possible through extensive irrigation projects by the Federal, State, Local and private entities. The question addressed here is whether such considerable change in the surface characteristics might have an effect on the long term climate record.

2. DATA AND METHOD

To answer this question, we gathered all available data for the region and even digitized many years ourselves. The daily TMax and TMin temperatures were obtained from several sources, mainly the newly digitized COOP data released by NCDC. However, these data records have significant discontinuities which must be assessed before utilizing the technique of homogeneous segment construction.

Over 1600 pages of metadata were manually studied and information entered which indicated potential breaks in every station record. Forms such as B-23, B-44, 530, 531, 4005, 4017, 4025, 4302, and 4303 were examined. (These metadata forms are now archived in digital image format.) We documented every station change indicated on the forms. Once the information was systematically placed and collated in a spreadsheet, we reexamined all meta-data and determined those points in time when a discontinuity occurred. This aspect of the research was especially tedious and inserted a level of subjective interpretation into the process.

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At each identified event, a breakpoint was inserted into the station's time series. Thus a single station in effect would be represented by several disjoint segments, or in terms of mathematical equivalency, into several different stations (Christy 2002).

The stations were divided into two strata, the San Joaquin Valley (<130 m elevation, 18 stations) and the Sierra Nevada Mountains (>130 m, 23 stations) Fig. 1. This separated stations in the irrigated valley from the foothills and mountains of the Sierras. When the breakpoints were applied, there were 112 Valley segments and 137 Mountain segments. A few non-recorded breakpoints were included after neighbor comparisons of first difference time series. Because of few opportunities for overlapping calculations in the earliest years, the time series will begin in 1910.

Most breakpoints (assumed to be discontinuities) arose from station moves. A break was identified when a station moved a distance of at least 3 m. Though this distance is minuscule compared to meteorological space scales, what we often found was that the new location usually differed in some other aspect besides location alone. In one case, a 7m location change took the instrument shelter out of a sprinkler's watering pattern. Other small moves changed the exposure relative to nearby buildings. Breaks were also recorded when new instrumentation was installed or a major repair of the station infrastructure was noted.

At this point our dataset consisted of several segments of daily temperature data stratified by season, elevation and diurnal event (i.e. TMax and TMin). Because there were multiple overlapping segments, there was no unique solution of intersegment biases which would produce a perfectly merged time series.

We applied a technique from mathematical graph theory to determine the optimum bias solution, one value for each segment, so that all segments, once debiased, were referenced to one base. Bias solutions for each elevation (Valley and Sierra), each variable (TMax and TMin) and each season were computed. This produced 16 total time series.

3. IRRIGATION

The Mediterranean climate of the San Joaquin Valley is characterized by a hot, dry season from May through October. Average annual precipitation totals in the valley range from 12 to 30 cm while orographically enhanced amounts in the mountains may exceed 200 cm. Usually, less than 10% falls during May to October.

Irrigated acreage in the five counties of Central California (Merced, Madera, Fresno, Kings and Tulare) has risen by a factor of 5 over the 20th century. Early systems were simply diversion canals which redistributed water to areas near the available rivers. During the 20th century, extensive, multi-year storage reservoirs were built to hold back spring runoff for release throughout the year or from year to year for agriculture. In addition, concrete-lined canals stretching over 100 km were constructed to allow for large deliveries of water.

Today, the pre-20th century San Joaquin Valley is fondly remembered as the Serengeti of North America. An estimated 10,000 grizzly bears, hundreds of thousands of antelope and hundreds of millions of migrating water fowl lived in the valley for at least a portion of each year. Rivers flowed uninterrupted to the Delta region and supported significant salmon runs. With the stoppage of the rivers and their diversion to irrigated land (an average acre requires over 1m of water per year) the ecosystem changed dramatically. Without irrigation, the valley environment would be characterized as very dry and desert-like from late spring to late fall every year. With very low humidity, such an environment saw diurnal temperature ranges of over 15°C in the dry season. Additionally, the hard, dry natural surface had little heat capacity and relatively high albedo.

4. RESULTS

We calculated trends for each season and elevation layer for the 1910-2003 period. TMin and TMax time series are shown in Figs. 2 and 3 for each season. The most remarkable difference in trends among the Valley and Sierra stations is found in summer (JJA).

The numerical values of the trends for all seasons are shown in Fig. 4. Most prominent are the TMin trends for the Valley stations, all being significantly positive.

TMax trends are revealing in a different way. The Valley JJA trend is the only season that has a modestly non-zero trend (negative). The Sierra station trends are all essentially indistinguishable from zero. Error estimates were generated in a variety of ways, with the error bars shown determined from the statistics of the time series. The lighter bars were determined from a random removal of a portion of the segments (5%, 10%, 15% and 20%) and reconstructing the time series without them. These lighter bars indicate the median trend using the segment removal test. Though the dark bars are calculated from the largest sample (all of the segments) and give us the highest confidence in their magnitude, if error does exist, it is likely in the direction demonstrated by the lighter bars. In any case, none of the difference-trends are significantly different when comparing the two methods of error determination.

Our hypothesis at this point is that irrigation has altered the surface energy balance of the valley floor, causing nighttime temperatures to remain warm. There are three possibilities related to irrigation. First, the additional water vapor supplied through evaporation, not present formerly, enhances the downward flux of thermal radiation. Second, the additional vapor allows aerosols to reach the swelling point at which they become very active in the thermal spectrum. Last, the moist ground and vegetation absorb solar energy during the ubiquitous cloudless days, and release the energy in the evening.

At this point our view is that the last process is the dominant one. Preliminary calculations indicate the enhanced water-vapor greenhouse effect would be relatively small while the humidity does not usually exceed the 80% threshold to initiate aerosol swelling. Thus, the presence of liquid water in the ground and vegetation (with lower albedo) increases the thermal capacity of the surface, thus keeping the nighttime temperatures warmer than would be otherwise through sensible heat flux.

During the day, however, it is likely that enhanced evaporation would induce lower values of TMax. This is consistent with the declining TMax trend in JJA for the Valley (Fig. 2b and 4).

Our next step is to test our hypothesis with a high resolution, mesoscale model with significant boundary layer physics to determine if our conjectures are supported.

In the broader sense, one should note that the annual trends of the valley and foothills (Fig 4) are quite different. We hypothesize that this difference is due to irrigation. It is also obvious that whatever the forcing is that contributes to these trends is likely not global in nature, such as forcing from carbon dioxide. Such a forcing should likely be apparent at all elevations.

5. REFERENCES

Christy, J.R., 2002: When was the hottest summer? A State Climatologist struggles for an answer. Bull. Am. Metor. Soc., 83, 723-734.

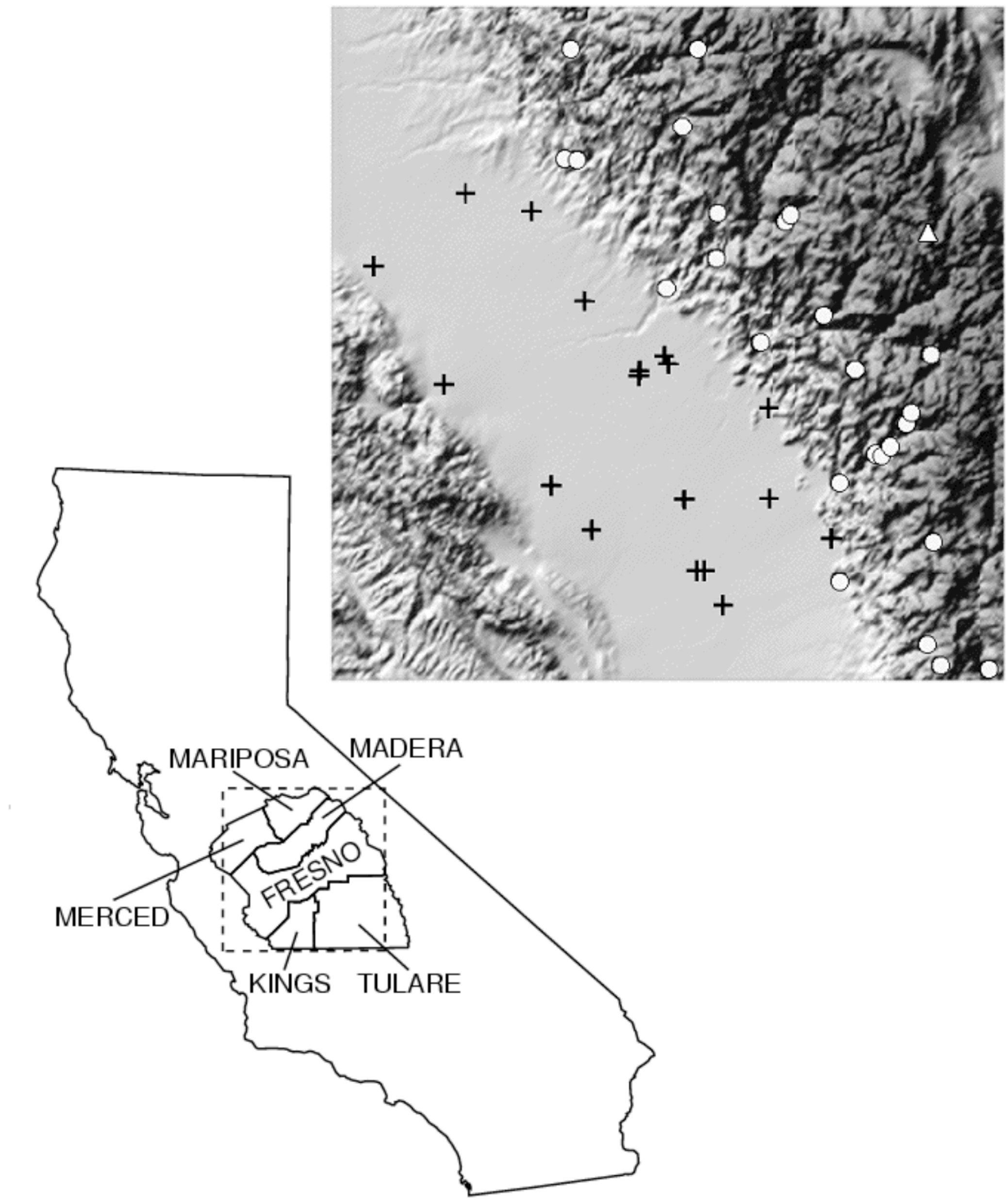
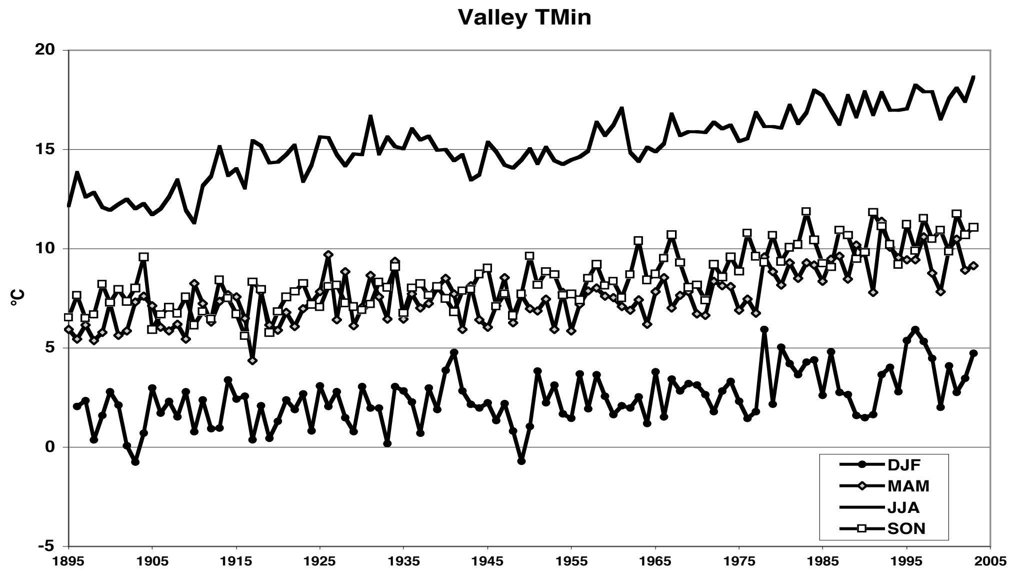


Fig. 1. Location of stations used in this study. Elevation levels: valley <130m, mountain >130m. A single station may be represented by more than one indicator on the map due to location changes.



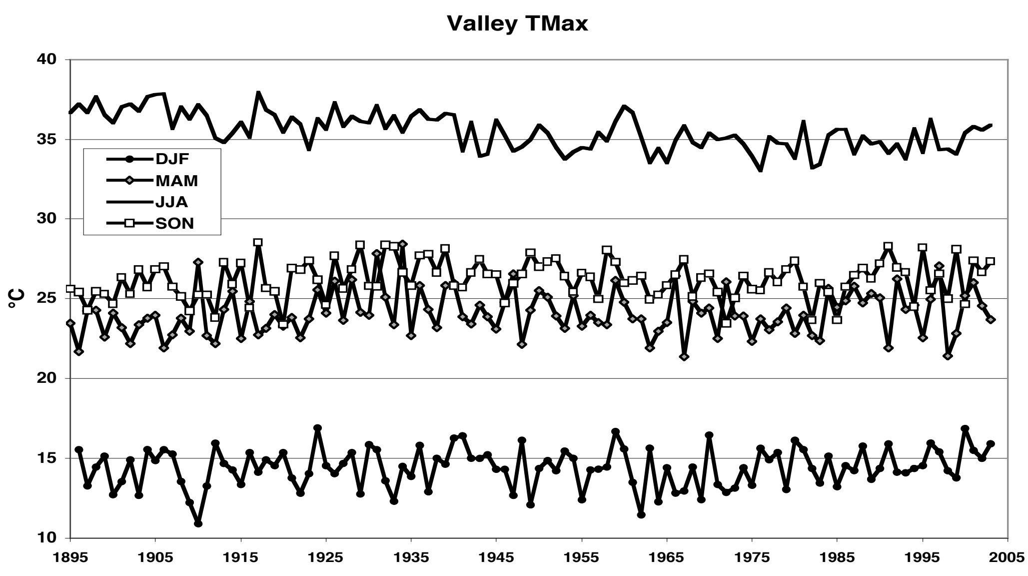
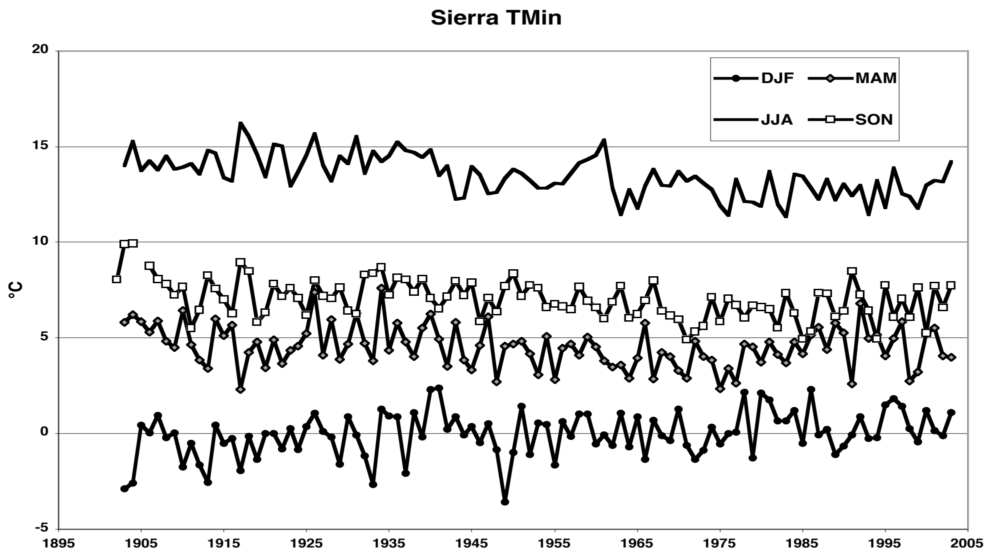


Fig. 2a: (Top) Time series of seasonal TMin based on 18 Valley stations. Fig. 2b (Bottom) as in 2a for TMax.



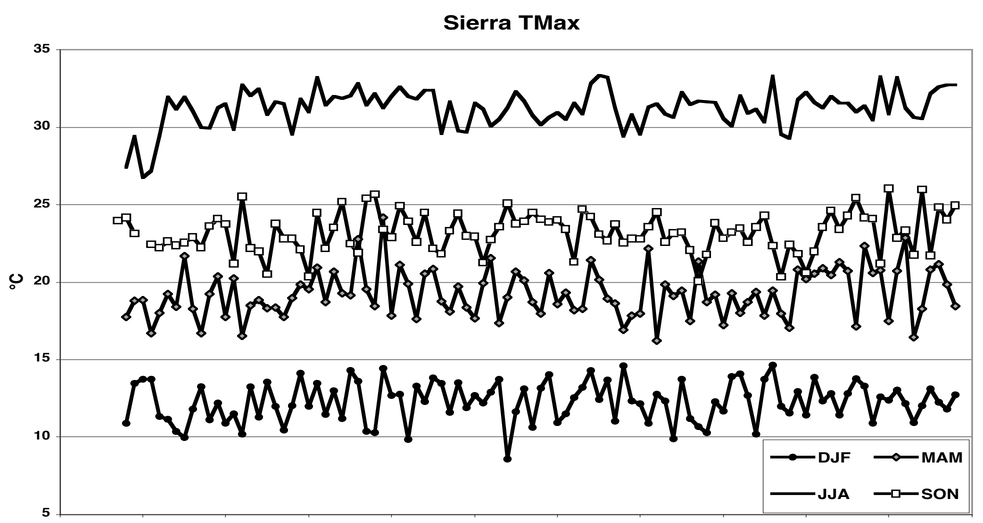


Fig 3a (Top) time series of seasonal TMin for 1910-2003 based on 23 Sierra stations. Fig. 3b, as in 3a for TMax.

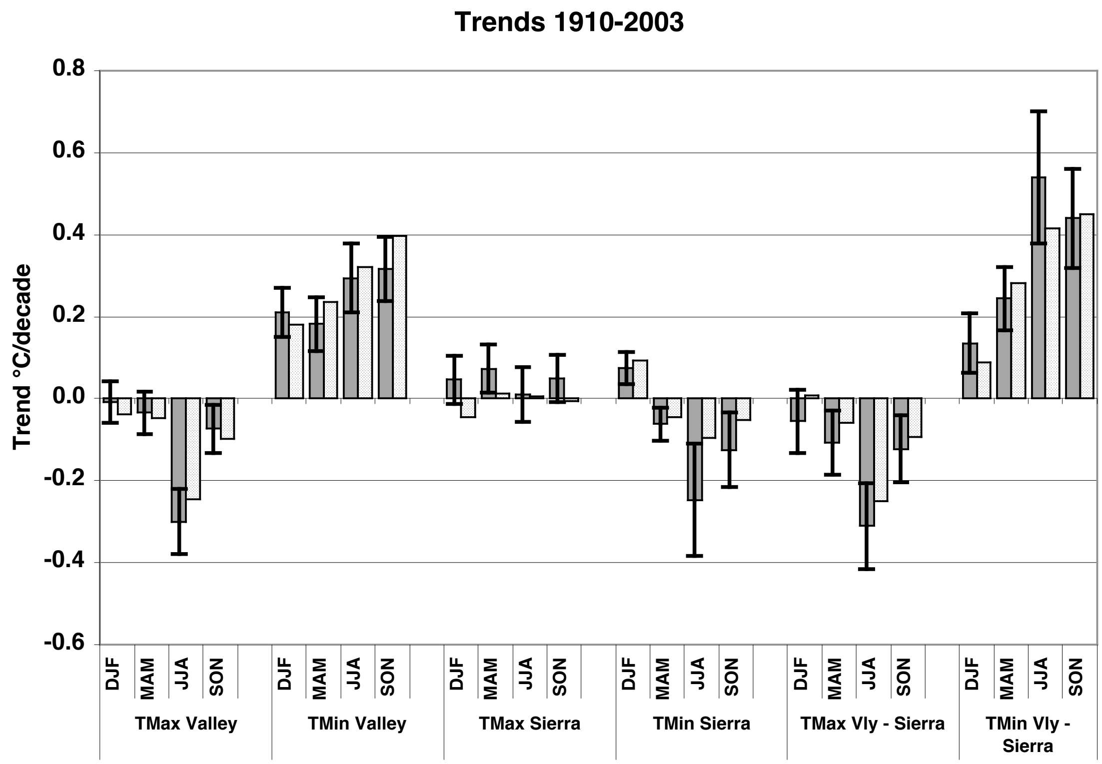


Fig. 4. Bar chart of seasonal temperature trends of daily maximum and minimum temperatures. Differences (Valley minus Sierra) for each season for TMax and TMin are shown at right.