A SENSITIVITY ANALYSIS OF SOUTHWESTERN CLIMATE

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ABSTRACT

We provide here an estimate of the extent that modern climate in the southwest US is sensitive to changes in several parameters that reflect global climatic changes. For the purposes of this study, we define modern climate as mean monthly values for the months of February and August (called winter and summer, respectively) of temperature and precipitation, at points representing the average of cells of dimension 7.5′ on a side. The area studied surrounds the drainage basin of Death Valley, California.

The influence of sea surface temperature, general wind patterns (seasonal extremes of these) and sea level are of interest. Each is studied at two levels (Table 1). Sea surface temperatures for these two months are specified by cubic polynomial equations derived by a stepwise regression procedure from gridded data (CLIMAP, 1981) at a spacing of 2° latitude and longitude.

Table 1. Variables analyzed and values applied

| Variable | Nominal Value | Perturbation |
|---|---|---|
| Winter wind direction | 102° | ± 10° |
| Summer wind direction | 65° | ± 10° |
| Winter sea surface temp. | cubic | ± 3° |
| Summer sea surface temp. | cubic | ± 3° |
| Sea level | 0 m | ± 15 m |

We examine the response of five regions for study of sensitivity (Figure 1). The mean of nine points in a 3 x 3 grid was computed in each region. This tends to reduce the magnitude of random variability at the sites. The sites were chosen and the grids located so that they were relatively homogeneous in elevation and climatic character. This step also tends to reduce the magnitude of random variability at the sites. Both of these effects together will tend to magnify the signal-to-noise ratio in identifying effects that influence climate in these areas.

We used a computer simulation with regression-based equations as described elsewhere (Craig and Roberts, 1988). A completely crossed experimental design was employed with a five-way analysis of variance to determine significance. A digital elevation model represents topography and wind vectors are assumed to be linear.

Conclusions

The Mojave desert (areas 4 and 5) is not sensitive to any of the five factors considered. Since these factors would probably be the mediators of climate change in the area that could be introduced by global climatic change, it appears that the Mojave desert is relatively stable under almost any broad climatic change.

The northern area (1, 2 and 3) is sensitive to shifts in the direction of winds which bring in Pacific air masses. These significantly change summer temperatures in the northeast. Changes in the source of the summertime monsoonal winds affect summertime precipitation in the Sierras and wintertime precipitation in the northeast.

Winter SSTs affect wintertime temperatures in the northwest (areas 1 and 2) and summertime temperatures in the northeast (areas 2 and 3). As summertime SSTs change, the pattern of summertime precipitation in the Sierras will respon -- warmer summertime SSTs lead to lesser summertime precipitation there. All of these relations are summarized in Figure 1 and Table 2. The ANOVA suggested no impact of changing sea level by 15m.

Table 2. Relation between factors studied in the Analysis of Variance and the response variables.

| Factor | Direction | Response | Area | Direction |
|---|---|---|---|---|
| Pacific Winds | more southerly | summer temp. | 2,3 | warmer |
| Monsoon Winds | more southerly | summer ppt. | 1 | increase |
| | | winter ppt. | 3 | increase |
| Winter SSTs | warmer | winter temp. | 1,2 | cooler |
| | | summer temp. | 2,3 | warmer |
| Summer SSTs | warmer | summer ppt. | 1 | decrease |

The responses listed in Table 2 have been presented for the direction of change of the factors that might be anticipated for a particular scenario -- warming of the climate such as might accompany a global increase of carbon dioxide. The factors listed were found to have F values at least 10 times the 0.05 significance level and all are 'pure effects'. That is, no interaction terms are significant at that level. Because of this, we suggest that a two-stage response to climatic change could occur in this area. The first would be in response to the more rapid shift in atmospheric circulation patterns. The second, perhaps several thousand years later, would derive from the equilibration of sea surface temperatures to the new global energy balance. This two-stage spatially-varied response may be typical of climate change in the southwest US.

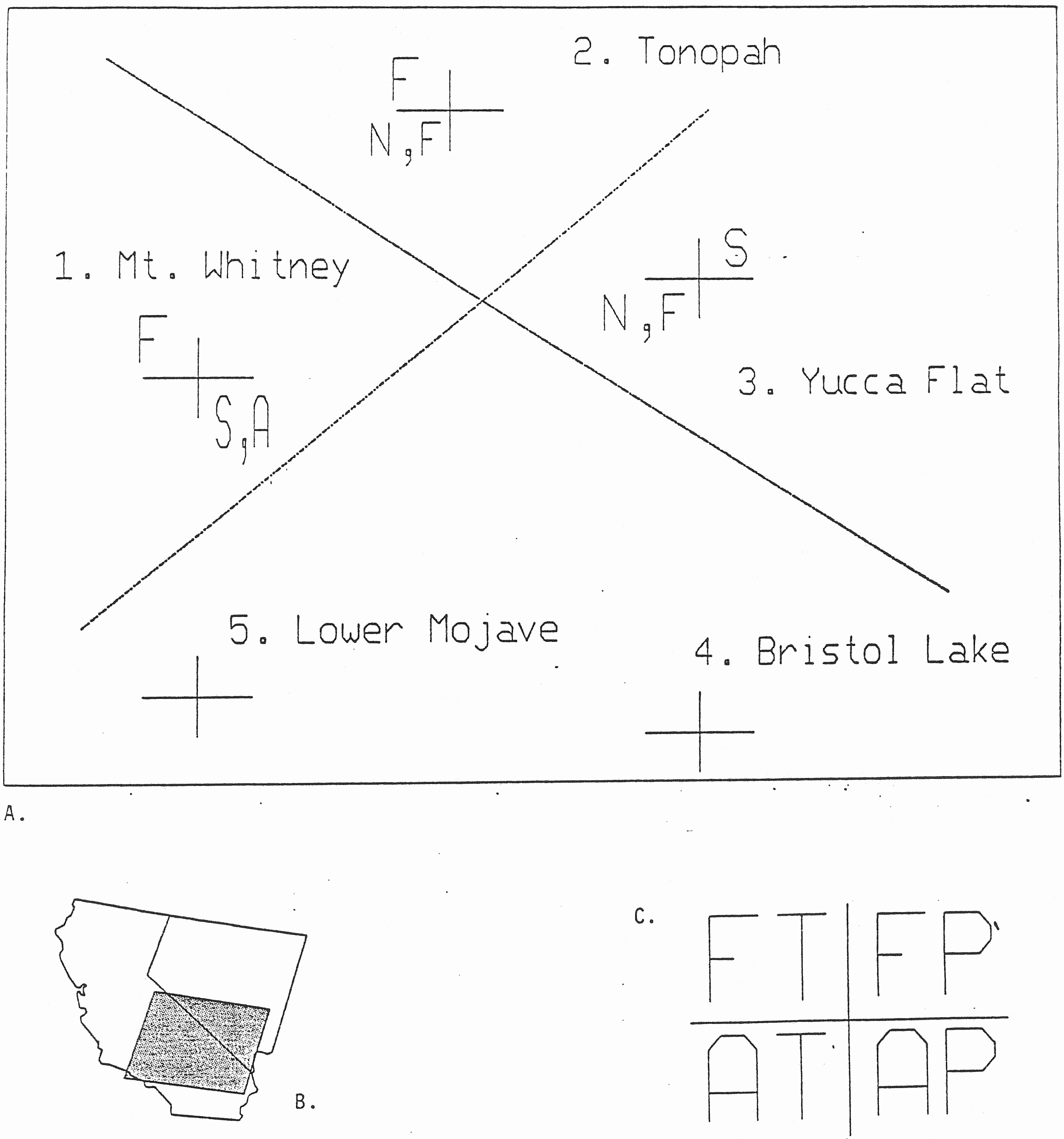


Figure 1. (A) Index Map showing location of study area, (B) Results of analysis showing significant factors at each site: F=February SST, A=August SST, N=Northern (westerly winter) winds, S=Southerly (summer monsoon) winds, (C) Response variables, February (F) and August (A) Temperature (T) and Precipitation (P). Thus, for example, at Tonopah, February SSTs (F) significantly affect February temperature (F).