7.1 CLIMATE DIVISION NORMALS DERIVED FROM TOPOGRAPHICALLY-SENSITIVE CLIMATE GRIDS

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1. INTRODUCTION

Each of the 48 contiguous states has been subdivided into as many as 10 climatic divisions, often coinciding with county boundaries and always covering the entire geographical extent of every state. 344 separate divisions have been identified for the contiguous United States. Monthly temperature and precipitation data have been calculated for each division for the period 1895 to present. Climatic divisions have also been identified for Alaska, Hawaii, and U.S. possessions, but their periods of record are shorter. Guttman and Quayle (1996) provided a detailed overview and history of climatic divisions.

Uses of climate division data are many and varied. These include assessments of severity of individual months or years, estimates of energy demand, studies of variability of local weather, drought planning and mitigation, and long-term climate change.

Climate division averages are simple unweighted arithmetic means of monthly data from all representative stations within a division. Prior to 1931 there were relatively few stations available for division average estimates, so statewide averages developed by the U.S. Department of Agriculture were used; division data were extracted from the statewide values via regression techniques.The chief deficiencies of the climate division data are:

1. Averages were computed from all available stations, and since the number of stations varies over time, the averages are based on a changing set of station values;
2. Most of the stations used were low elevation stations. Guttman and Quayle (1996) point out that high elevation stations in a division were often removed from the data sets prior to computation of averages because they were considered “unrepresentative.”

The intent of the current project is to calculate divisions with an orographically-sensitive climate model and compare the results of that analysis with the published estimates of divisional precipitation. This addresses deficiency 2. above.

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2. METHODS

Annual 1961-1990 precipitation averages for United States climate divisions were derived from two sources. The first source was the existing divisional normals available from the NCDC. The second made use of a gridded, peer-reviewed 1961-1990 mean monthly and annual precipitation analysis prepared for USDA-NRCS. This analysis, performed by the Oregon State University Spatial Climate Analysis Service, used the PRISM modeling system (Daly et al., 1994, 2001, 2002, USDA-NRCS 1998). Grid resolution was 2.5 minutes latitude/longitude, or about 4 km. Divisional averages were derived from the PRISM gridded analysis by obtaining a polygon coverage of the United States climate divisions and averaging the mean annual precipitation of all grid cells falling within each division. Some error was introduced into this process by the coarse spatial scale of the divisional polygon coverage. An example of this is discussed below. The divisional averages from NCDC and PRISM were then compared and contrasted by calculating a difference map.

3. RESULTS AND DISCUSSION

A map of the percent difference between the 1961-1990 PRISM and NCDC division means, expressed as 100*(PRISM-NCDC)/NCDC, is shown in Figure 1. The NCDC and PRISM means are within 10% over nearly the entire eastern United States. Exceptions are two divisions in New England, and the Florida Keys, where PRISM is 10-25% higher. In Florida, the discrepancy appears to be due to the coarse resolution of the divisional boundary polygon file, which “cut off” the actual Keys from the division. Since the Keys are significantly drier than the mainland, it is likely that this omission caused the PRISM mean to be high. In New England, both of these divisions are mountainous. The discrepancies here are probably due to elevational biases in the NCDC station data available. Such biases are discussed further below.

In the western US, the discrepancies between the PRISM and NCDC averages are quite large, with PRISM always being higher. PRISM is up to 25% higher in portions of every western state. Differences are largest in the northern Rockies of northwest Wyoming, Montana, and Idaho, where PRISM can be 50-100% higher. All of these regions are characterized by remote, mountainous terrain, where station density is low.

The Yellowstone Drainage, a division for which the PRISM estimate is over 100% higher than the

NCDC average, was selected for more detailed analysis. Figure 2 shows the elevational distribution of stations NCDC used in its divisional average, those stations within the division that were used in the PRISM analysis, and the frequency distribution of actual elevations in the divisions, as derived from a 15 second (~500 m) digital elevation model (DEM). The DEM elevation distribution shows that elevations of 2000-3000 m are common, with a small, secondary maximum at 1200-1400 m. The total elevational range is 1200-3600 m. NCDC used a total of four stations to generate its divisional average, and the station elevations are at or below the most frequent elevation range. The highest station was below 2400 m. The PRISM analysis used a total of twelve stations, from a combination of COOP and SNOTEL networks. The elevation distribution of these stations is much more representative of the actual elevations within the Yellowstone Drainage, with five stations above 2400 m. In addition, PRISM calculated a unique precipitation-elevation relationship for each 4-km DEM grid cell and applied these relationships to the grid cells in a spatially unbiased manner. This is a critical step, because precipitation increases strongly with elevation in this, and many other mountainous areas. The result is a more robust areal precipitation estimate that accounts for elevational gradients and is resistant to the varying density and placement of stations.

4. CONCLUSIONS

Annual 1961-1990 precipitation averages for United States climate divisions were derived from two sources: (1) existing divisional normals from the NCDC; and (2) averages derived with GIS from a gridded, peer-reviewed, analysis performed for the USDA by the OSU Spatial Climate Analysis Service with the PRISM modeling system. Much of the US east of the Rockies showed little or no difference in the averages. In the West, however, discrepancies were large, with the PRISM averages always being higher than the NCDC averages. A closer examination revealed that these discrepancies were due to two main factors: (1) the stations selected for the NCDC averages were biased low, and hence, dry in their elevational distribution; and (2) the simple averaging of all stations within a division did not account for the elevational or climatic representativeness of the stations used. The PRISM analysis used a more representative selection of stations, including USDA-NRCS SNOTEL sites, and applied local precipitation-elevation relationships to the actual terrain, further reducing the elevational bias. Therefore, it is likely that the NCDC divisional precipitation averages over much of the western United States are low, and that the PRISM averages are closer to the actual values.

5. REFERENCES

Daly, C., W. P. Gibson, G.H. Taylor, G. L. Johnson, P. Pasteris. 2002. A knowledge-based approach to the statistical mapping of climate. Climate Research, in press.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33: 140-158.

Daly, C., G.H. Taylor, W. P. Gibson, T.W. Parzybok, G. L. Johnson, P. Pasteris. 2001. High-quality spatial climate data sets for the United States and beyond. Transactions of the American Society of Agricultural Engineers 43: 1957-1962.

Guttman, N. and R. Quayle, 1996. A historical perspective of U.S. climate divisions. Bulletin of the American Meteorological Society, 77:293-303.

USDA-NRCS. 1998. PRISM Climate Mapping Project--Precipitation. Mean monthly and annual precipitation digital files for the continental U.S. USDA-NRCS National Cartography and Geospatial Center, Ft. Worth TX. December, CD-ROM.

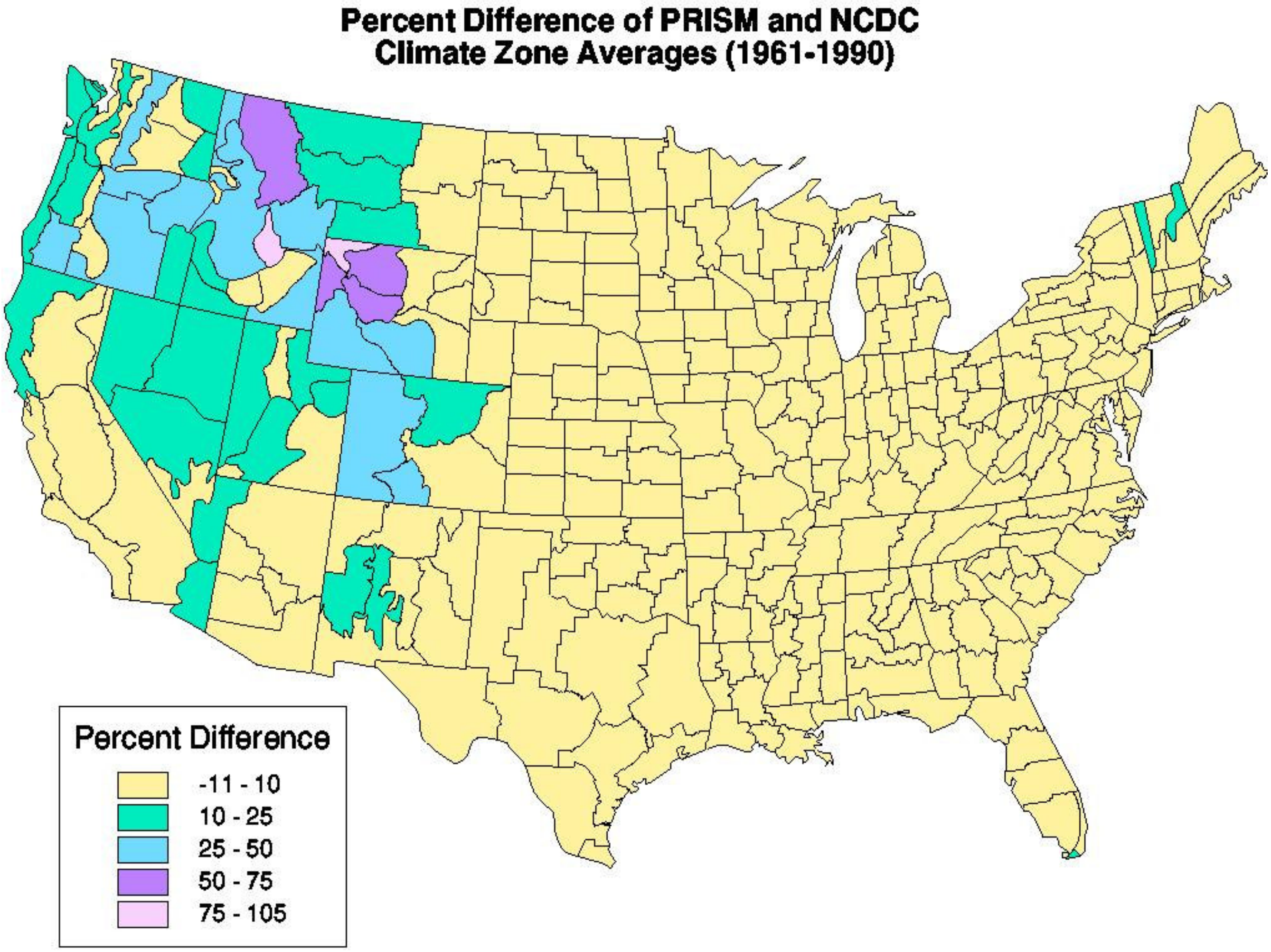

Figure 1. Percent difference between the 1961-1990 PRISM and NCDC division means

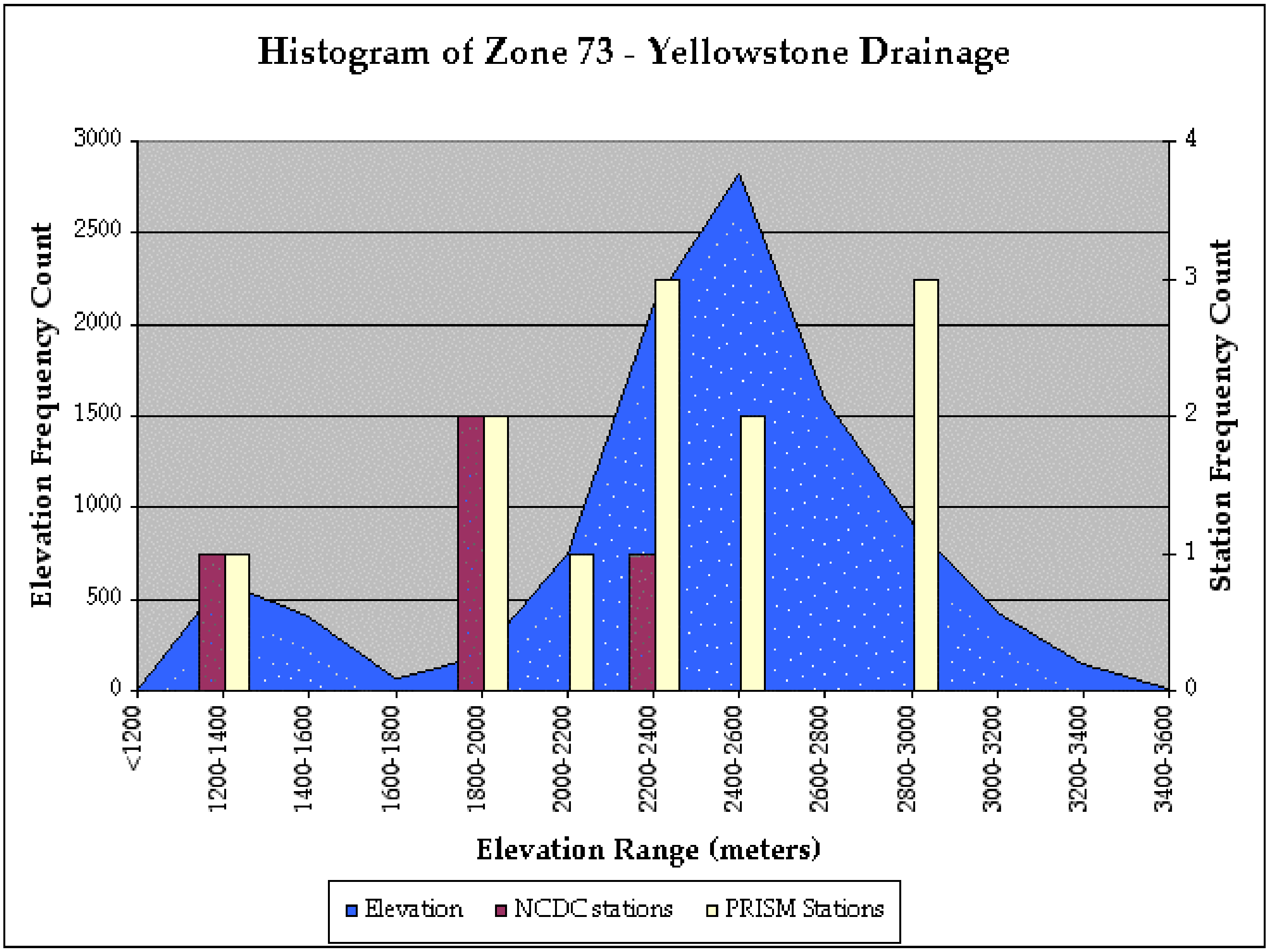

Figure 2. Elevational distribution of stations NCDC used in its divisional average, those stations within the division that were used in the PRISM analysis, and the frequency distribution of actual elevations in the divisions, as derived from a 30 second (~500 m) digital elevation model (DEM).