TETRA TECH

Date: February 18, 2013

Recipient: Tamara Presser, Central Coast Regional Water Quality Control Board

Project: Preparation of 85th and 95th Percentile Precipitation Maps

Subject: Task 3 Memo – Confidence Interval Accuracy of the 85th and 95th percentile 24-hour Rainfall Depths

The Task 2 memo (dated February 8, 2013) previously outlined the methodology for generating the 85th and 95th percentile rainfall depths for the Central Coast Region. The objective of Task 3 is to statistically evaluate the accuracy of the previously generated maps. Our interpretation of the scope of work requirement divides the evaluation process into two components:

1. Test the accuracy of the mapped 85th and 95th percentile contours versus values computed directly from observed NCDC time series.
2. Calculate the allowable tolerance for an 85th or 95th percentile 24-hour storm computed using an independent gage.

This memo is divided into two sections that describe each of those aspects. The last section of this memo proposes some future analysis for consideration.

Step 1: Validating Mapped Data against Observed

As noted in the Task 2 memo, the original NCDC stations had previously been quality controlled to patch missing or unreported periods of record and disaggregate accumulated intervals using rainfall from nearby gages. The first step was to validate the accuracy of the mapped 85th and 95th percentile rainfall values against observed data from the NCDC stations. Of the 44 stations, those with the highest data quality (at least 98 percent coverage over the sixty-year period between 10/1/1949 and 9/30/2010) were selected for comparison against both the PRISM grid value and the interpolated contour values that were derived using the Inverse Distance Weighting (IDW) method. Figure 1 is a plot of observed rainfall quantity and quality for all 44 regional NCDC stations over the sixty year period of interest, sorted by elevation. The stations having at least 98 percent complete coverage over the 60 year period are highlighted in RED on the figure. There were 13 stations that met these criteria. The computed 85th and 95th percentile rainfall depths for these stations are summarized in Table 1, along with elevation, percent complete, and annual average rainfall depth. Table 2 shows the observed versus mapped values (both PRISM and IDW) for the 85th and 95th percentile rainfall depths. The relative color scale highlights absolute percent difference between the observed and mapped values. Figure 2 shows one-to-one comparisons of observed versus mapped 85th and 95th percentile values.

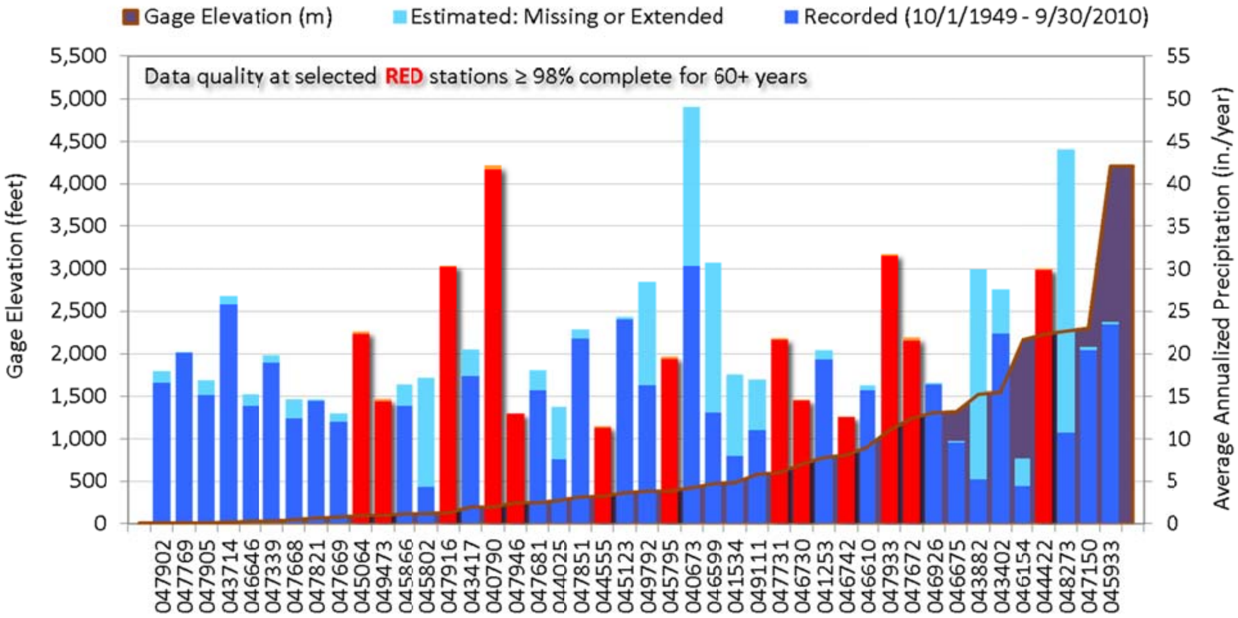


Figure 1. Observed rainfall quantity and quality for regional NCDC rainfall, sorted by increasing gage elevation.

Table 1. Table of the highest quality Central Coast Regional NCDC stations used for map validation

Observed Rainfall Station (NCDC)		Elevation (feet)	Percent Complete	Annual (in./year)	24-hour Rainfall (in.)	
ID	Station Name				85th	95th
046742	PASO ROBLES MUNI AP	810	100%	12.53	0.83	1.31
047916	SANTA CRUZ	130	100%	30.40	1.19	1.98
047946	SANTA MARIA PUBLIC AP	242	100%	12.92	0.85	1.36
047731	SAN CLEMENTE DAM	600	99%	21.75	1.00	1.71
046730	PASO ROBLES	700	99%	14.55	0.89	1.39
049473	WATSONVILLE WATERWORKS	95	99%	22.56	0.99	1.58
047672	SALINAS DAM	1,245	98%	21.85	1.26	2.12
045795	MONTEREY	385	98%	19.60	0.84	1.27
044422	JUNCAL DAM	2,227	98%	30.04	2.07	3.96
047933	SANTA MARGARITA BOOST	1,100	98%	31.78	1.62	2.67
044555	KING CITY	320	98%	11.48	0.73	1.22
045064	LOMPOC	95	98%	14.68	0.93	1.50
040790	BIG SUR STATION	200	98%	42.14	1.65	2.78

Table 2. Mapped versus observed rainfall depth comparison, sorted by increasing 85th percentile rainfall depths

Observed Rainfall Station (NCDC)		85th Percentile (in.)			95th Percentile (in.)		
ID	Station Name	NCDC	IDW*	PRISM*	NCDC	IDW*	PRISM*
44555	KING CITY	0.73	0.72	0.69	1.22	1.13	1.16
46742	PASO ROBLES MUNI AP	0.83	0.88	0.98	1.31	1.41	1.58
45795	MONTEREY	0.84	0.80	0.94	1.27	1.27	1.47
47946	SANTA MARIA PUBLIC AP	0.85	0.90	0.89	1.36	1.40	1.43
46730	PASO ROBLES	0.89	0.91	0.89	1.39	1.45	1.44
45064	LOMPOC	0.93	1.01	0.95	1.50	1.49	1.53
49473	WATSONVILLE WATERWORKS	0.99	0.88	0.66	1.58	1.37	1.04
47731	SAN CLEMENTE DAM	1.00	1.02	1.04	1.71	1.69	1.75
47916	SANTA CRUZ	1.19	1.20	1.08	1.98	1.97	1.81
47672	SALINAS DAM	1.26	1.38	1.27	2.12	2.28	2.14
47933	SANTA MARGARITA BOOST	1.62	1.39	1.50	2.67	2.35	2.53
40790	BIG SUR STATION	1.65	1.59	1.62	2.78	2.69	2.73
44422	JUNCAL DAM	2.07	1.72	1.87	3.96	3.20	3.58

* Red color gradient highlights increasing absolute percent difference between observed NCDC and mapped values (IDW and PRISM)

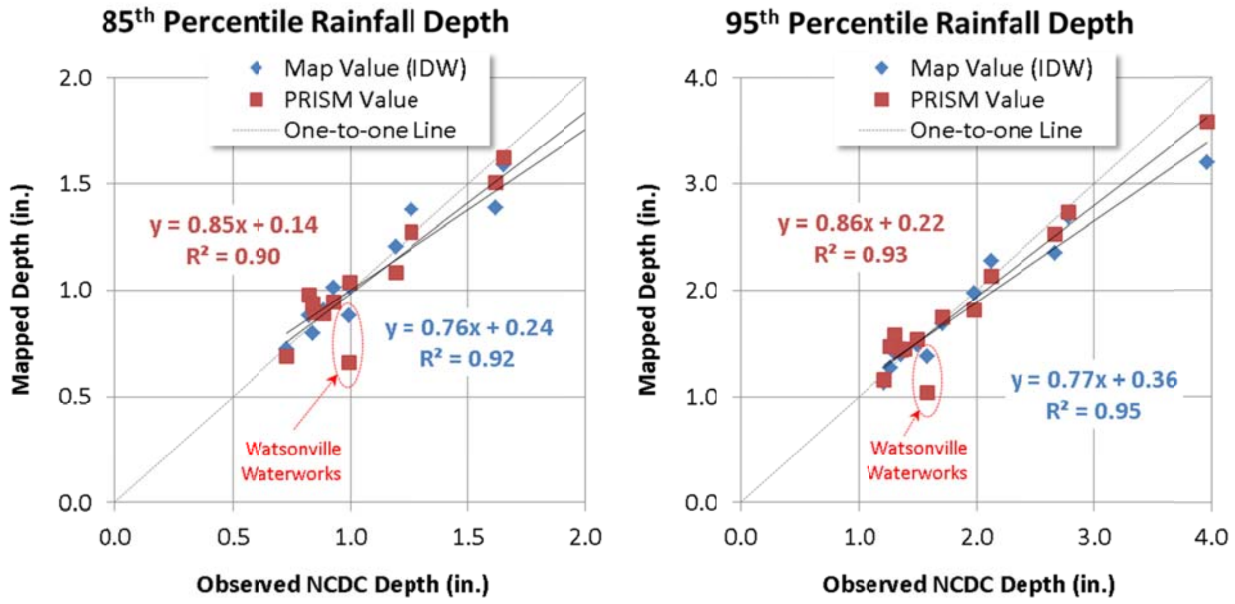


Figure 2. One-to-one comparisons of observed versus mapped 85th and 95th percentile rainfall values.

The results show that both the coincident PRISM grid values and the results from the IDW method provided good estimates of the observed 85th and 95th percentile rainfall values, with the IDW having a slightly higher R^2 value in both instances. The difference between using the nearest PRISM versus the interpolated IDW contour value is most pronounced in places with rapid spatial change between grids (such as the Watsonville Waterworks gage, as called out in Figure 2). Both PRISM and IDW slightly under-predicted the most extreme wet gage on the map (Juncal Dam). For NCDC gages located between PRISM grids, using the IDW interpolated contour values increased the goodness-of-fit in terms of slightly higher R^2. The slopes of the trend lines are lower for IDW than PRISM because the smoothing effect inherent in the IDW method (as applied for the two maps produced in this study) has implications on the rainfall magnitude, although most pronounced at gages with higher peak rainfall volumes.

Step 2: Calculating Confidence Intervals

The second objective of this analysis was to apply an appropriate statistical approach to evaluate the confidence (or allowable tolerance) for an 85th or 95th percentile 24-hour storm computed using an independent gage. Because the statistics of interest for this study are the 85th and 95th percentile rainfall values, they represent two discrete temporal points. Confidence intervals cannot be calculated on a single point; therefore, for this analysis they were computed at any given point using the values at surrounding points within a fixed buffer area of the point. Figure 3 is a conceptual view of the surrounding grid cells to a given grid cell *n*.

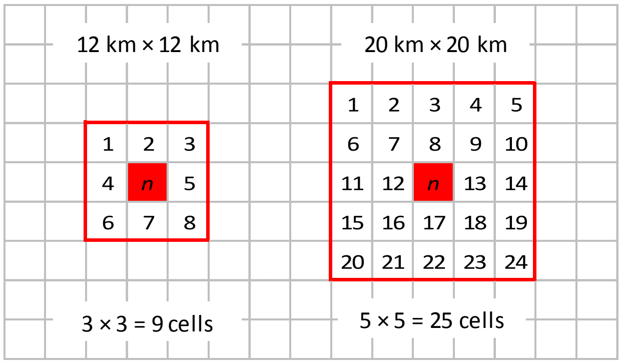


Figure 3. Conceptual view of surrounding cells to a given cell *n*.

To minimize the influence of orographic effects, the smallest buffer area (using a 9-cell sample space) was used to compute the mean, standard deviation, and confidence intervals for each grid in the study area. Because the confidence interval only qualifies the mean value of the sample space, they cannot be directly applied to the mapped values. Therefore, maps of *relative* confidence intervals were derived by dividing the confidence interval value by the mean value for each grid sample. Figure 4 shows the relative confidence intervals on the mean 85th percentile rainfall depths, while Figure 5 shows the relative confidence intervals on the mean 95th percentile rainfall depths for the Central Coast region. As expected, places where rainfall has rapid spatial changes have wider confidence interval bands than places where the spatial change is more gradual. Central Coast Water Board staff can use this information as guidance when evaluating whether or not to accept an externally computed percentile value proposed by an applicant as follows:

1. Less tolerance (i.e., variance from the mapped value) should be given for places where the confidence interval bands are narrow because there is less uncertainty about the spatial variation of the computed value. The Water Board should decide upon an allowable threshold for the relative confidence interval.
2. For places where the bands are relatively wide, further review and greater attention should be paid to ensure that the proposed values are reflective of topographic variability. For those areas,

gage values should be used if they are proven to be more representative of the project site (i.e. high data quality and long period of record). Otherwise, the map should be used.

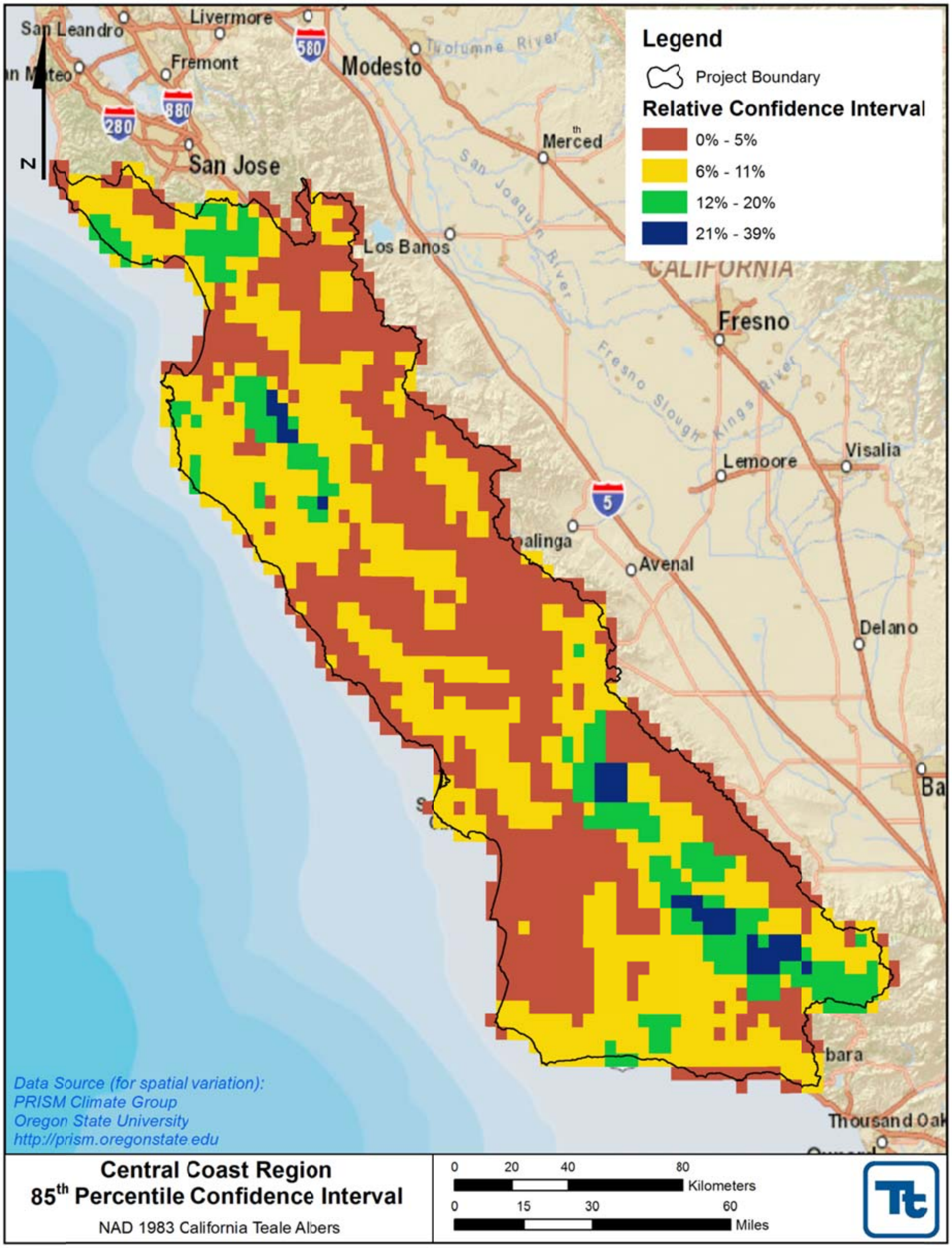
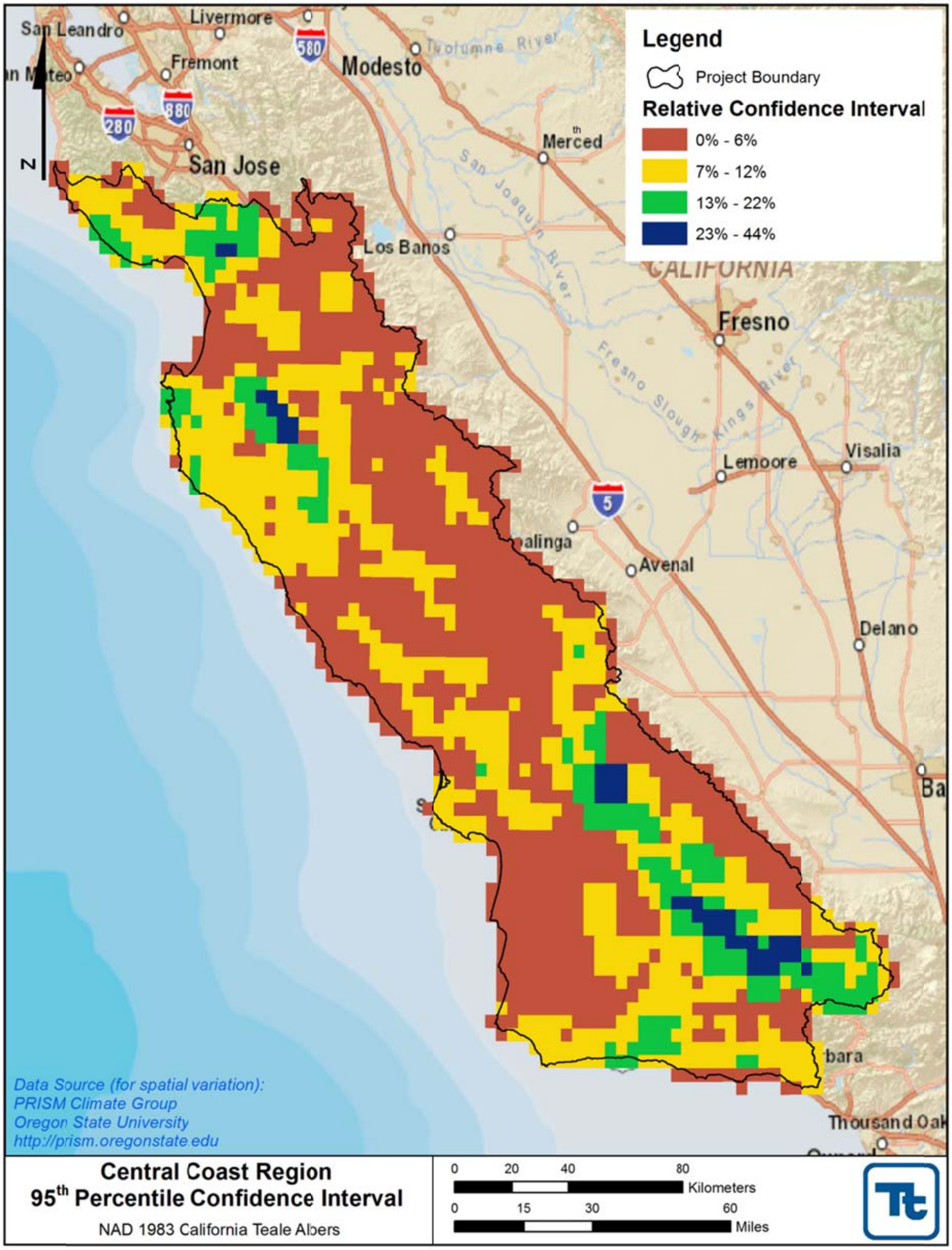


Figure 4. Relative confidence intervals on mean 85th percentile rainfall values.



Data Source (for spatial variation):
PRISM Climate Group
Oregon State University
http://prism.oregonstate.edu

Figure 5. Relative confidence intervals on mean 95th percentile rainfall values.

Next Steps

Because of the strong orographic influences inherent in the mapped 85th and 95th percentile rainfall depths, additional analysis is needed to further define map tolerances. Setting universal tolerances for distance and elevation change for the entire region is not recommended because of the spatial variation of the precipitation patterns. In some areas, the allowable distance of a gage from the project site may be far because the precipitation patterns are consistent in that particular subregion. In other areas, the distance will be much shorter due to rapidly changing patterns. Further, allowable tolerance will change depending on the direction in which one moves away from any given point on the map. A simple statistical test was used by Zou and Donner (2008) to test if the mean values of two comparable samples differ at a specified α-value of significance. For this example, the 9-cell sample space shown in Figure 3 was assumed as the baseline condition. The mean and confidence intervals associated with the 9-cell sample space were tested against the mean and confidence intervals for the coincident 25-cell sample space at $\alpha = 0.05$ (i.e. 95 percent confidence interval). For any given grid, the test comparing the mean computed using 25 cells versus the mean computed using 9 cells yielded one of three possible outcomes: (1) the mean value was significantly higher, (2) the mean value was significantly lower, or (3) there was no significant difference between means computed using 25 cells versus 9 cells.

Places that tested significant were places where moving farther away from the grid cell impacted the value of the 85th or 95th percentile rainfall depth. This can be refined by using a finer-resolution resampled grid (i.e. 200 meters or finer instead of 4 km) that more closely matches the interpolated IDW contours. This test also did not consider the direction in which one moved away from the grid; however, it still highlighted areas where special attention should be paid if the physical distance between the project location differ by more than 8 to 12 km. Test results for the 85th and 95th percentile values are shown in Figure 7 and Figure 8, respectively. It is important to note that these maps are overly-conservative (most areas register no significant change) because the mean values for 25 grids also include the 9 interior grids as part of the mean. However, there is no GIS utility that will automatically calculate incremental bands of distance relative to any given point. This would involve additional research and programming to implement. A possible future enhancement to this study would be to develop a set of map attributes showing the minimum allowable distance in any given direction away from a certain point (i.e. north, south, east, west), where the statistical test first registers a difference in the mean value. Figure 6 shows a conceptual search space for this directional significance test. This approach would involve calculating the mean value of grid cells that intersect quadrants of concentric bands of distance moving incrementally away from any given grid cell, and testing whether that value is significantly different from the mean associated with the closest band the cell, which is used as a baseline reference condition assumed to not be different.

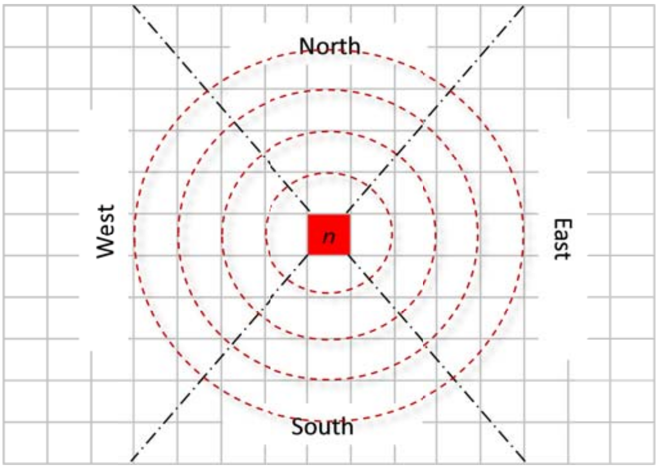


Figure 6. Conceptual search space for a proposed directional significance test.

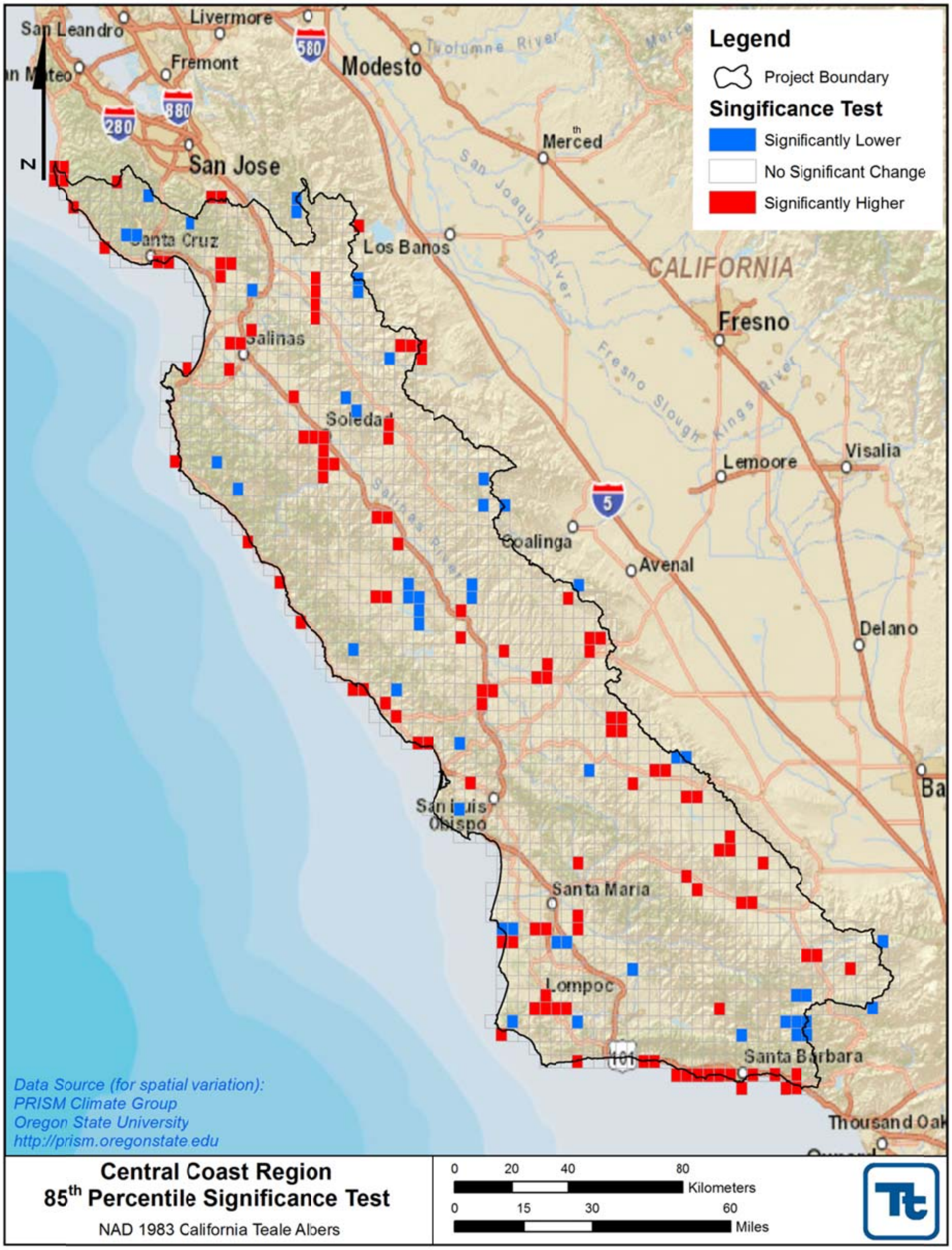


Figure 7. Significance test results for mean 85th percentile rainfall computed using 25 versus 9 grids.

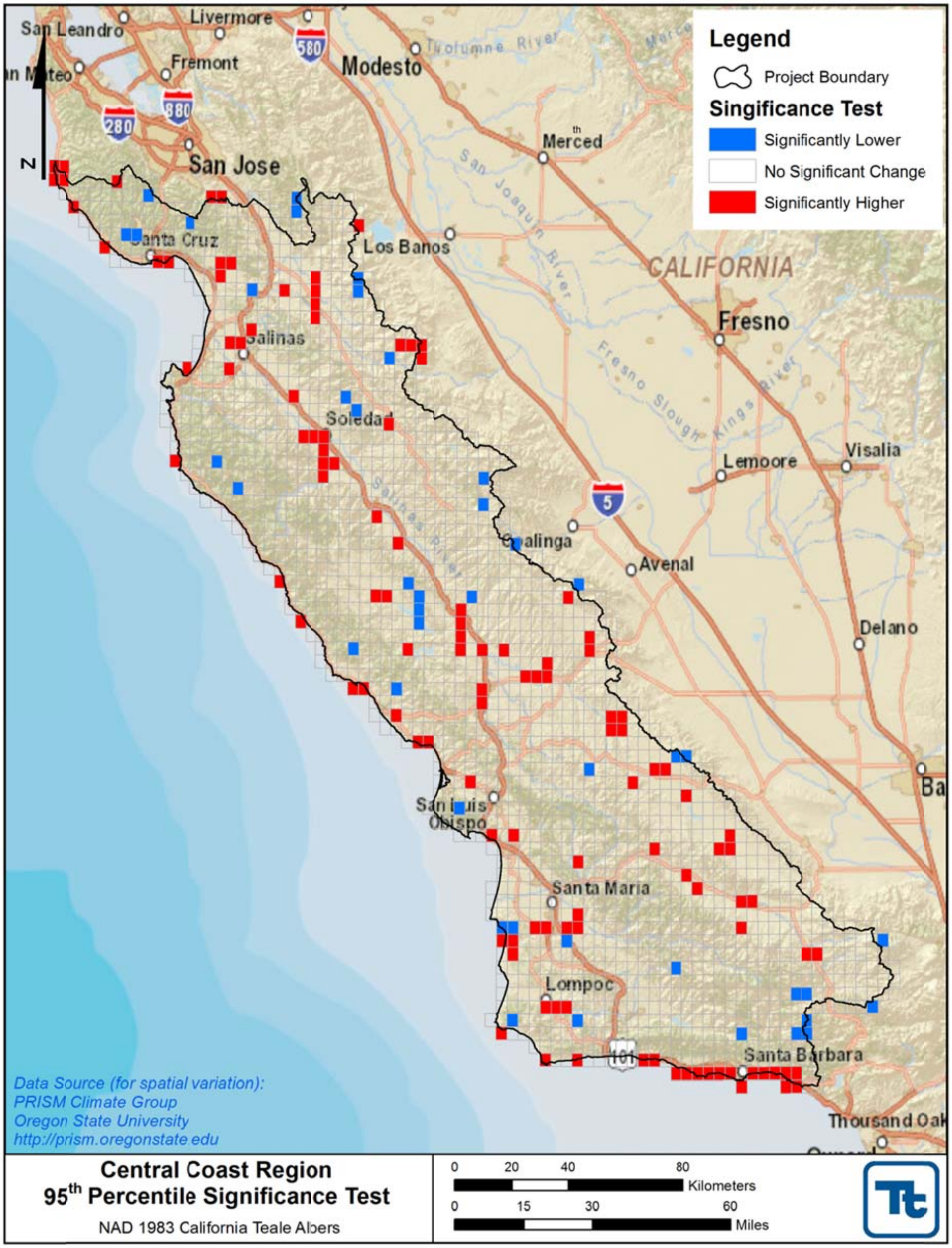


Figure 8. Significance test results for mean 95th percentile rainfall computed using 25 versus 9 grids.

References

Zou GY, Donner A. 2008. Construction of confidence limits about effect measures: A general approach. Statistics in Medicine 27:1693-1702