Appendix A.6 Temporal distributions of annual maxima

1. Introduction

Temporal distributions of annual maxima are provided for 6-, 12-, 24-, and 96-hour durations. The temporal distributions are expressed in probability terms as cumulative percentages of precipitation totals at various time steps. To provide detailed information on the varying temporal distributions, separate temporal distributions were also derived for four precipitation cases defined by the duration quartile in which the greatest percentage of the total precipitation occurred.

Stations were grouped into fourteen climate regions, shown in Figure A.6.1, and separate temporal distributions were derived for each climate region. Regions were delineated based on extreme precipitation characteristics expressed through 24-hour mean annual maximum (MAM) estimates, mean annual precipitation (MAP), elevation, latitude, and proximity to the coast. In some cases, transitional regions were created between very distinct climate regions.

Climate regions. Some of the highest precipitation amounts occur in region 1, where precipitation is orographically enhanced by the western facing Coastal Range Mountains as moisture-laden storms reach the shoreline. In transitional region 2 which is more inland, the elevation increases slightly, but as it is farther from the coast, precipitation amounts begin to decrease. To the south, region 7 is also influenced by the Coastal Range, but the terrain is not as varied and precipitation amounts are lower due to the stronger influence of the eastern Pacific high pressure that forces maritime storms to the north especially during the summer. Region 8 is a drier transitional region due to its leeward proximity to the Coastal Range.

Beyond these mountains, the low-lying interior Central Valley regions (5, 9 and 10) are cut off from the maritime moisture and receive much less precipitation. The more northern region 5 has relatively higher precipitation amounts than regions 9 and 10. Region 9 contains some of the lowest precipitation amounts in the state. MAP and MAM begin to increase in the transitional region 10 and then peak in the Sierra Nevada Range (regions 6 and 11). Region 6 may have lower elevations than region 11, but because it is farther north, it receives increased amounts of precipitation. In northeastern region 3, elevations remain high due to the Cascade Range and Sierra Nevada Range, but leeward characteristics relative to the moisture flow cause it to be a transitional zone into the lower precipitation amounts of region 4 which is part of North America's Great Basin.

In the south, region 12 comprises the LA Basin encircled by a series of mountains that stretch from west to east. This region has the highest precipitation amounts in southern California. Region 13 in southwest California along the coast is flanked by mountains on its northern and eastern sides but the region is so far south that it is impacted by fewer storms. The Cascade Range, Sierra Nevada and LA Basin mountains serve to cut off moisture to eastern California forming a very dry, desert climate particularly in the southeast (region 14). However, the southeastern desert region is susceptible to the Mexican Monsoon during the summer months where tropical Pacific moisture flows up from the southwest triggering brief but heavy downpours especially at higher elevations.

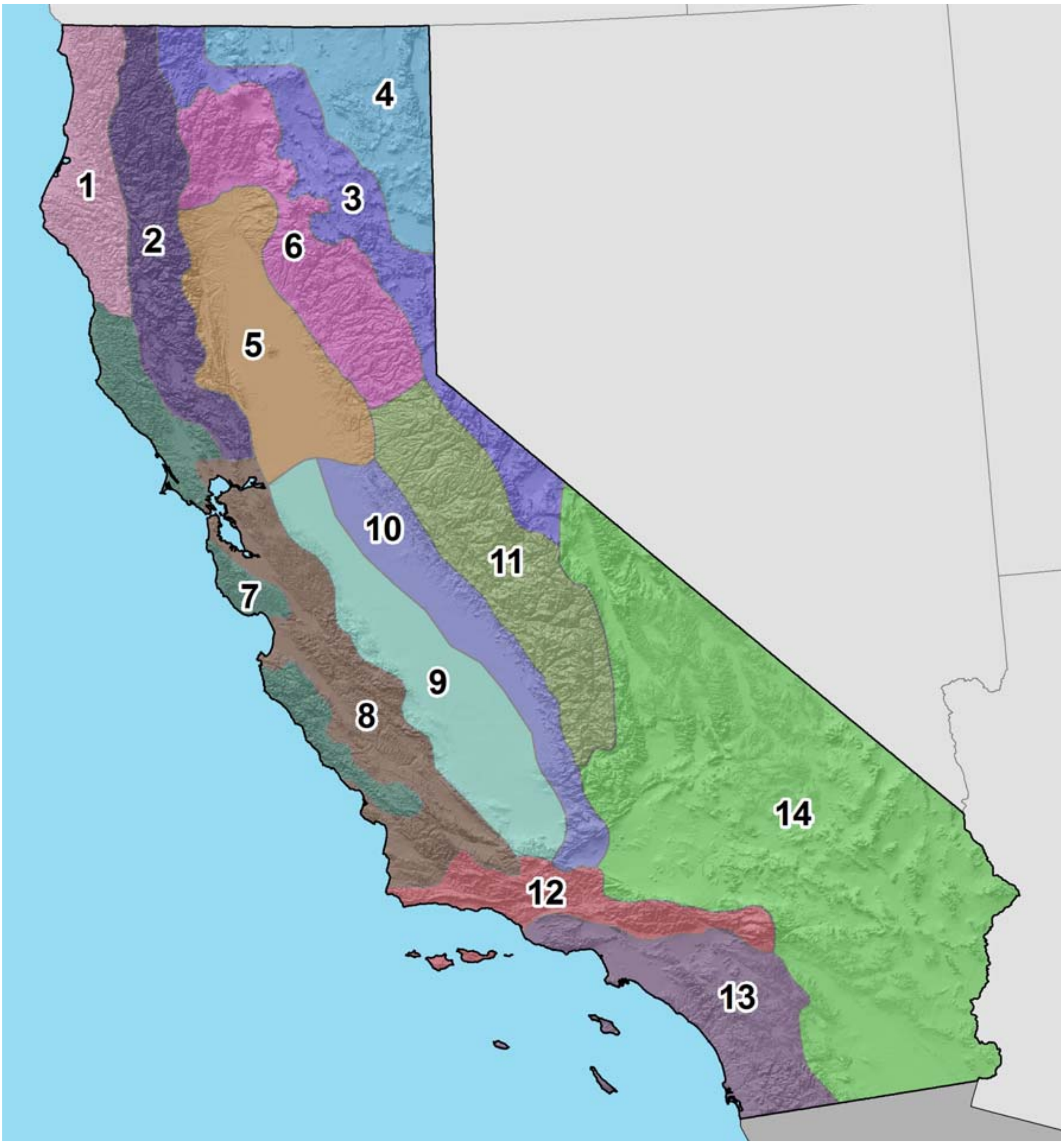


Figure A.6.1. Climate regions used for temporal distribution and seasonality analyses.

2. Methodology and results

The methodology used to produce the temporal distributions is similar to the one developed by Huff (1967) except in the definition of precipitation cases. In accordance with the way a precipitation case ('event') was defined for the precipitation frequency analysis, a precipitation case for the temporal distribution analysis was computed as the total accumulation over a specific duration (6-, 12-, 24-, or 96-hours). As a result, it may contain parts of one or more storms. Because of that, temporal distribution curves presented here may be different from corresponding temporal distribution curves obtained from the analysis of single storms.

Also, precipitation cases for this project always start with precipitation but not necessarily end with precipitation resulting in potentially more front-loaded cases when compared with distributions derived from the single storm approach. To reduce biases, a constraint was imposed to exclude cases with a continuous dry period that lasted for more than 30% of the duration. This restriction produced a less variant sample. By imposing the restriction on continuous dry periods, the number of cases available for temporal distribution analysis decreased with duration because long, continuous precipitation events occurred less frequently than continuous short-duration events. Cases were selected from the annual maximum series at each station. Table A.6.1 shows the total number of precipitation cases and number of cases in each quartile for each region for each selected duration.

For each precipitation case, cumulative precipitation amounts were converted into percentages of the total precipitation amount at one hour time increments. All cases for a specific duration were then combined and probabilities of occurrence of precipitation totals were computed at each hour. The temporal distribution curves for nine deciles (10% to 90%) were smoothed using linear programming method (Bonta and Rao, 1988) and plotted in the same graph. Figure A.6.2 shows as an example of temporal distribution curves for the four selected durations for region 13; time steps were converted into percentages of durations for easier comparison.

The cases were further divided into four categories by the quartile in which the greatest percentage of the total precipitation occurred. Table A.6.1 shows the numbers and proportion of precipitation cases used to derive the temporal distributions in each quartile. Unlike the cases of 12-, 24-, and 96-hour durations in which the number of data points can be equally divided by four, the cases of 6-hour duration contain only six data points and they cannot be evenly distributed into four quartiles. Therefore, in this analysis, for 6-hour duration, the first quartile contains precipitation cases where the most precipitation occurred in the first hour, the second quartile contains precipitation cases where the most precipitation occurred in the second and third hours, the third quartile contains precipitation cases where the most precipitation occurred in the fourth hour, and the fourth quartile contains precipitation cases where the most precipitation occurred in the fifth and sixth hours. This uneven distribution affects the number of cases contained in each quartile for the 6-hour duration. Figures A.6.3 through A.6.6 show the temporal distribution curves for four quartile cases for 6-hour, 12-hour, 24-hour and 96-hour durations, respectively.

Table A.6.1. Total number of precipitation cases and number (and percent) of cases in each quartile for selected durations for each designated climate region.

Duration	Region	All cases	First-quartile cases	Second-quartile cases	Third-quartile cases	Fourth-quartile cases
6-hour	1	424	66 (16%)	117 (28%)	149 (35%)	92 (22%)
	2	573	80 (14%)	177 (31%)	177 (31%)	139 (24%)
	3	583	107 (18%)	182 (31%)	168 (29%)	126 (22%)
	4	274	57 (21%)	82 (30%)	91 (33%)	44 (16%)
	5	883	143 (16%)	240 (27%)	313 (35%)	187 (21%)
	6	968	173 (18%)	241 (25%)	297 (31%)	257 (27%)
	7	775	103 (13%)	224 (29%)	295 (38%)	153 (20%)
	8	1573	258 (16%)	511 (32%)	539 (34%)	265 (17%)
	9	397	71 (18%)	127 (32%)	127 (32%)	72 (18%)
	10	394	88 (22%)	121 (31%)	114 (29%)	71 (18%)
	11	884	154 (17%)	269 (30%)	253 (29%)	208 (24%)
	12	1054	121 (11%)	276 (26%)	399 (38%)	258 (24%)
	13	1880	329 (18%)	561 (30%)	627 (33%)	363 (19%)
	14	693	150 (22%)	203 (29%)	213 (31%)	127 (18%)

Duration	Region	All cases	First-quartile cases	Second-quartile cases	Third-quartile cases	Fourth-quartile cases
12-hour	1	415	86 (21%)	122 (29%)	134 (32%)	73 (18%)
	2	561	100 (18%)	152 (27%)	202 (36%)	107 (19%)
	3	557	143 (26%)	178 (32%)	164 (29%)	72 (13%)
	4	228	53 (23%)	72 (32%)	74 (32%)	29 (13%)
	5	859	159 (19%)	231 (27%)	269 (31%)	200 (23%)
	6	958	172 (18%)	260 (27%)	299 (31%)	227 (24%)
	7	735	134 (18%)	228 (31%)	233 (32%)	140 (19%)
	8	1405	290 (21%)	460 (33%)	426 (30%)	229 (16%)
	9	319	82 (26%)	113 (35%)	73 (23%)	51 (16%)
	10	370	88 (24%)	117 (32%)	95 (26%)	70 (19%)
	11	867	140 (16%)	281 (32%)	269 (31%)	177 (20%)
	12	1012	165 (16%)	324 (32%)	340 (34%)	183 (18%)
	13	1730	363 (21%)	587 (34%)	490 (28%)	290 (17%)
	14	541	129 (24%)	182 (34%)	148 (27%)	82 (15%)
24-hour	1	404	87 (22%)	128 (32%)	120 (30%)	69 (17%)
	2	546	113 (21%)	183 (34%)	146 (27%)	104 (19%)
	3	490	133 (27%)	180 (37%)	108 (22%)	69 (14%)
	4	198	65 (33%)	59 (30%)	43 (22%)	31 (16%)
	5	793	195 (25%)	195 (25%)	202 (25%)	201 (25%)
	6	930	149 (16%)	264 (28%)	300 (32%)	217 (23%)
	7	680	164 (24%)	206 (30%)	173 (25%)	137 (20%)
	8	1275	443 (35%)	339 (27%)	285 (22%)	208 (16%)
	9	254	93 (37%)	60 (24%)	72 (28%)	29 (11%)
	10	310	90 (29%)	93 (30%)	75 (24%)	52 (17%)
	11	805	190 (24%)	287 (36%)	225 (28%)	103 (13%)
	12	881	220 (25%)	276 (31%)	237 (27%)	148 (17%)
	13	1492	451 (30%)	485 (33%)	338 (23%)	218 (15%)
	14	384	137 (36%)	109 (28%)	94 (24%)	44 (11%)
96-hour	1	350	111 (32%)	91 (26%)	87 (25%)	61 (17%)
	2	425	118 (28%)	126 (30%)	101 (24%)	80 (19%)
	3	316	100 (32%)	90 (28%)	81 (26%)	45 (14%)
	4	125	38 (30%)	37 (30%)	25 (20%)	25 (20%)
	5	497	177 (36%)	120 (24%)	114 (23%)	86 (17%)
	6	681	197 (29%)	155 (23%)	178 (26%)	151 (22%)
	7	477	170 (36%)	123 (26%)	102 (21%)	82 (17%)
	8	727	265 (36%)	170 (23%)	201 (28%)	91 (13%)
	9	128	43 (34%)	27 (21%)	31 (24%)	27 (21%)
	10	134	32 (24%)	36 (27%)	35 (26%)	31 (23%)
	11	431	157 (36%)	108 (25%)	115 (27%)	51 (12%)
	12	356	123 (35%)	66 (19%)	93 (26%)	74 (21%)
	13	583	219 (38%)	106 (18%)	128 (22%)	130 (22%)
	14	95	38 (40%)	18 (19%)	22 (23%)	17 (18%)

From the Precipitation Frequency Data Server, regional temporal distribution data are available in a tabular form for a selected location under the 'Supplementary information' tab or through the temporal distribution web page (http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_temporal.html). For 6-, 12- and 24-hour durations, temporal distribution data are provided in 0.5-hour increments and for 96-hour duration in hourly increments.

3. Interpretation

Figure A.6.2 shows as an example the temporal distribution curves of all precipitation cases in region 13 for the 6-, 12-, 24-, and 96-hour durations. Time steps were converted into percentages of total durations for easier comparison. Figures A.6.3 through A.6.6 show temporal distribution curves for first-, second-, third-, and fourth-quartile cases for 6-hour, 12-hour, 24-hour and 96-hour durations, respectively. First-quartile plots show temporal distribution curves for cases where the greatest percentage of the total precipitation fell during the first quarter of the duration (e.g., the first 3 hours of a 12-hour duration). The second, third, and fourth quartile plots are similarly for cases where the most precipitation fell in the second, third, or fourth quarter of the duration.

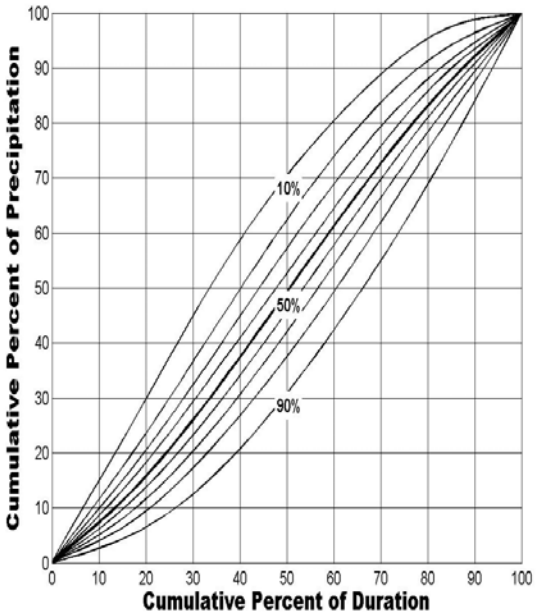
The temporal distribution curves represent the averages of many cases and illustrate the temporal distribution patterns with 10% to 90% occurrence probabilities in 10% increments. For example, the 10% curve in any figure indicates that 10% of the corresponding precipitation cases had distributions that fell above and to the left of the curve. Similarly, 10% of the cases had temporal distribution falling to the right and below the 90% curve. The 50% curve represents the median temporal distribution.

The following is an example of how to interpret the results using the figure (a) in the upper left panel of Figure A.6.5 for 24-hour first-quartile cases in region 13.

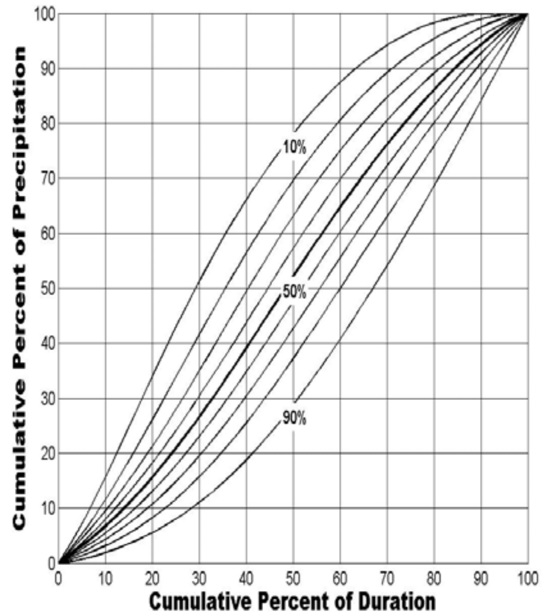
- In 10% of the first-quartile cases, 50% of the total precipitation fell in the first 4.3 hours (18% of duration) and 90% of the total precipitation fell by 12 hours (50% of duration).
- A median case of this type will drop half of the precipitation (50% on the y-axis) in approximately 6.2 hours.
- In 90% of the cases, 50% of the total precipitation fell by 10.6 hours (44% of duration) and 90% of precipitation fell by 22 hours (92% of duration).

Temporal distribution curves are provided in order to show the range of possibilities. Care should be taken in the interpretation and use of temporal distribution curves. For example, the use of different temporal distribution data in hydrologic models may result in very different peak flow estimates. Therefore, they should be selected and used in a way to reflect users' objectives.

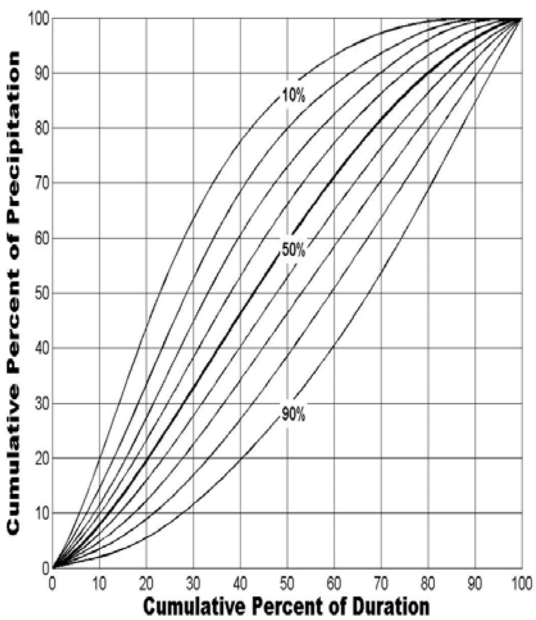
a) 6-hour duration



b) 12-hour duration



c) 24-hour duration



d) 96-hour duration

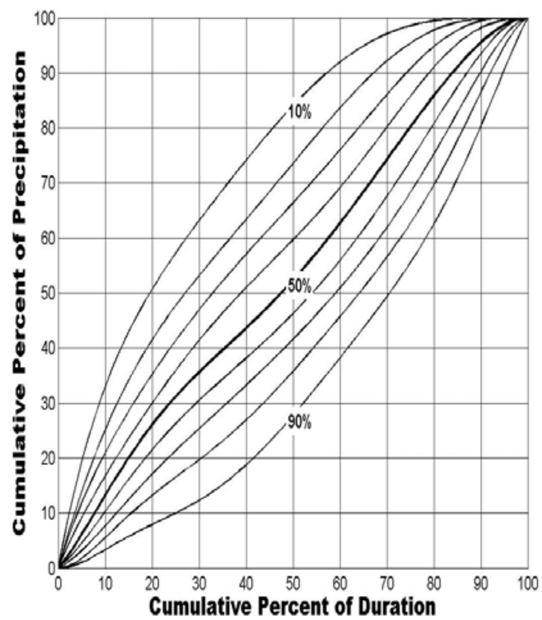
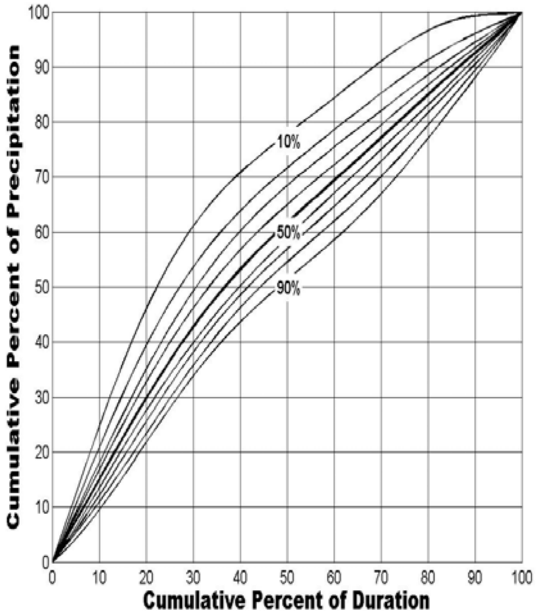
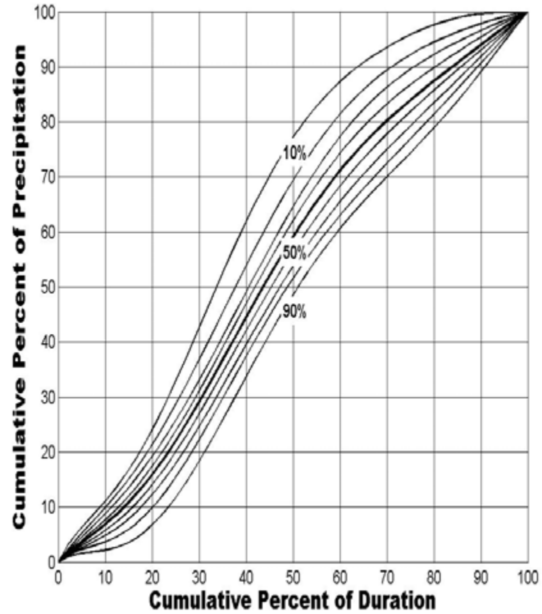


Figure A.6.2. Temporal distribution curves for region 13 all cases for: a) 6-hour, b) 12-hour, c) 24-hour, and d) 96-hour durations.

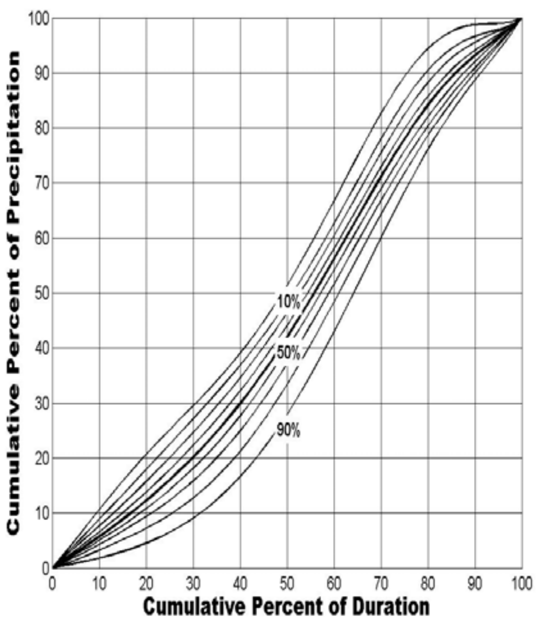
a) First-quartile



b) Second-quartile



c) Third-quartile



d) Fourth-quartile

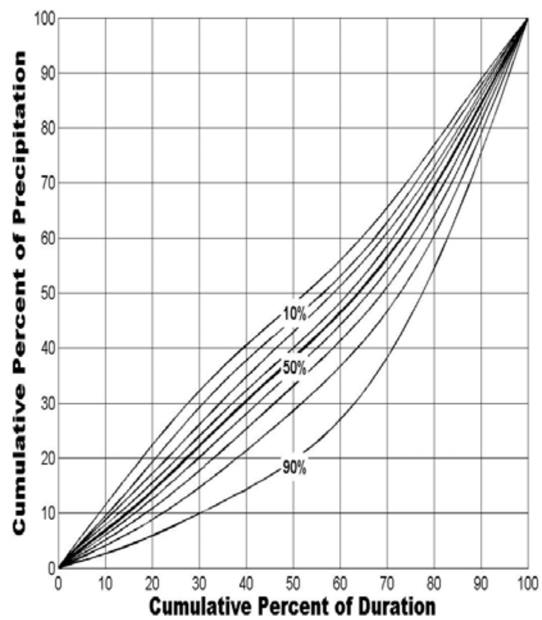
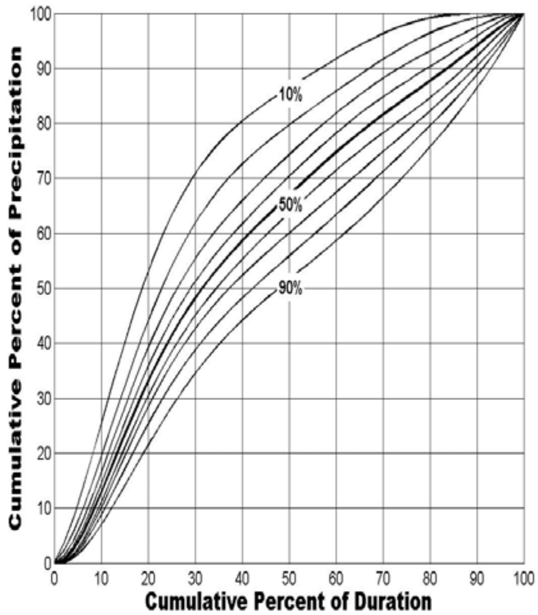
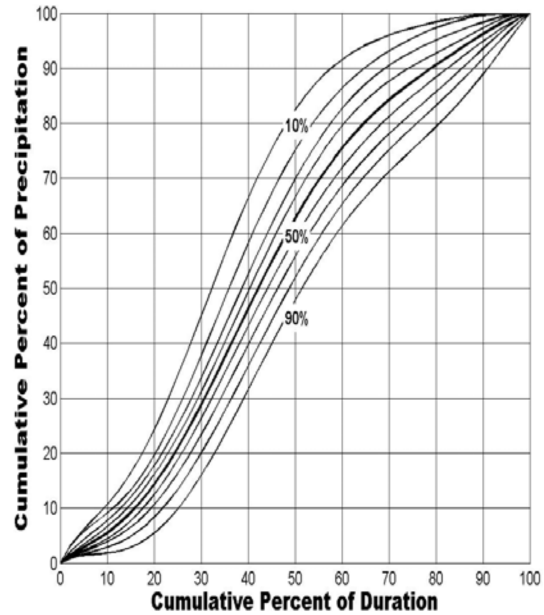


Figure A.6.3. 6-hour temporal distribution curves for region 13: a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.

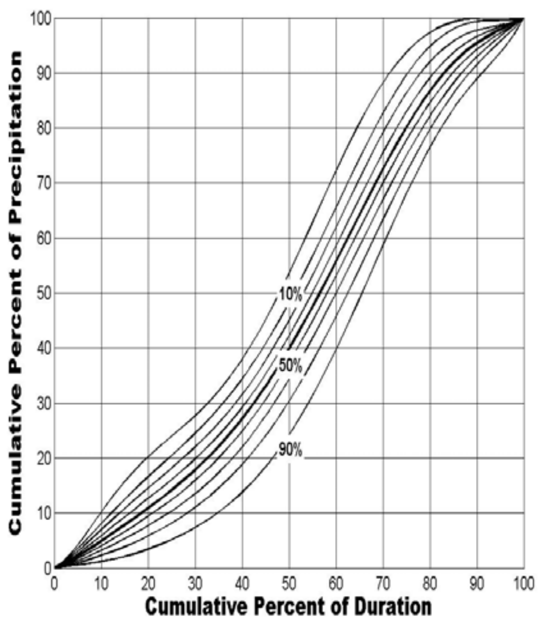
a) First-quartile



b) Second-quartile



c) Third-quartile



d) Fourth-quartile

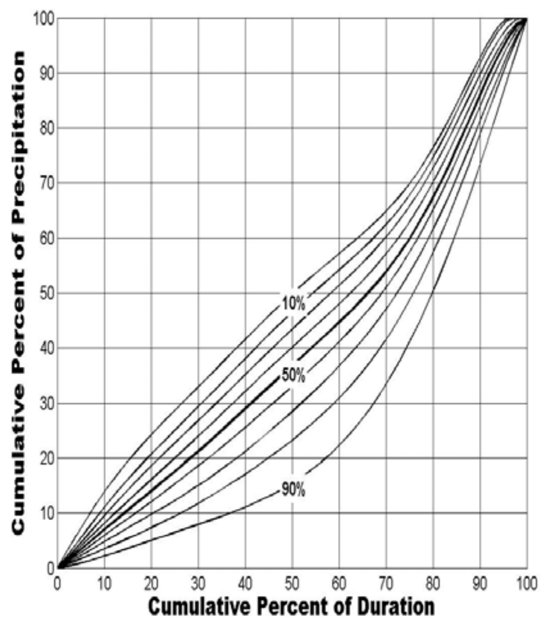
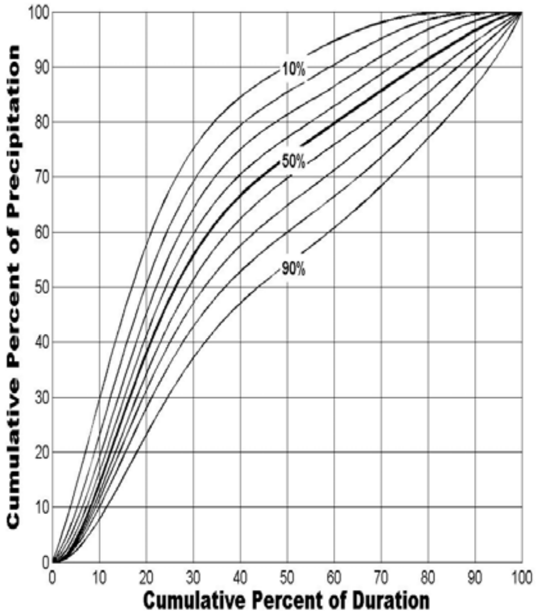
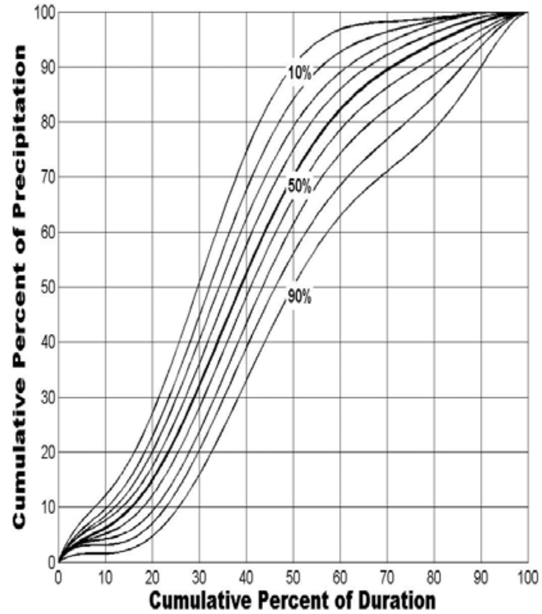


Figure A.6.4. 12-hour temporal distribution curves for region 13: a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.

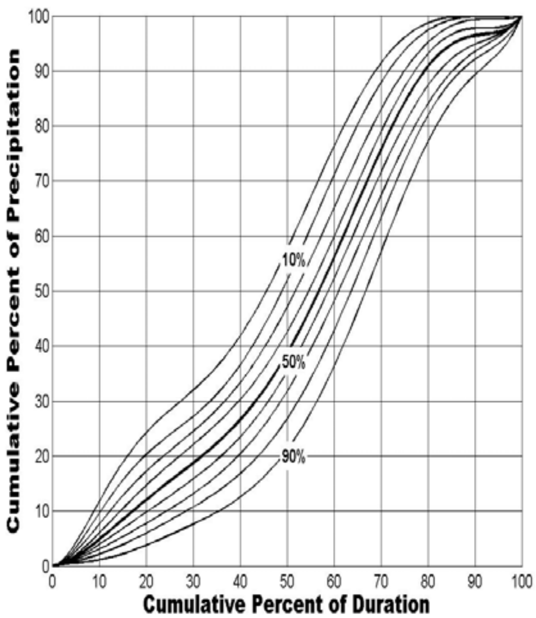
a) First-quartile



b) Second-quartile



c) Third-quartile



d) Fourth-quartile

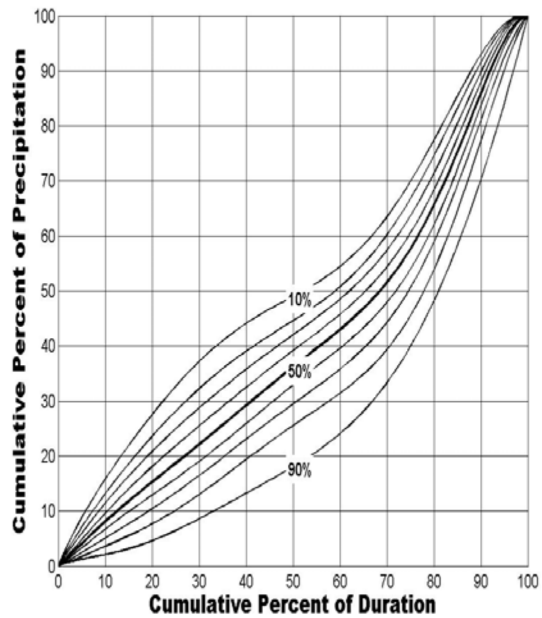


Figure A.6.5. 24-hour temporal distribution curves for region 13: a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.

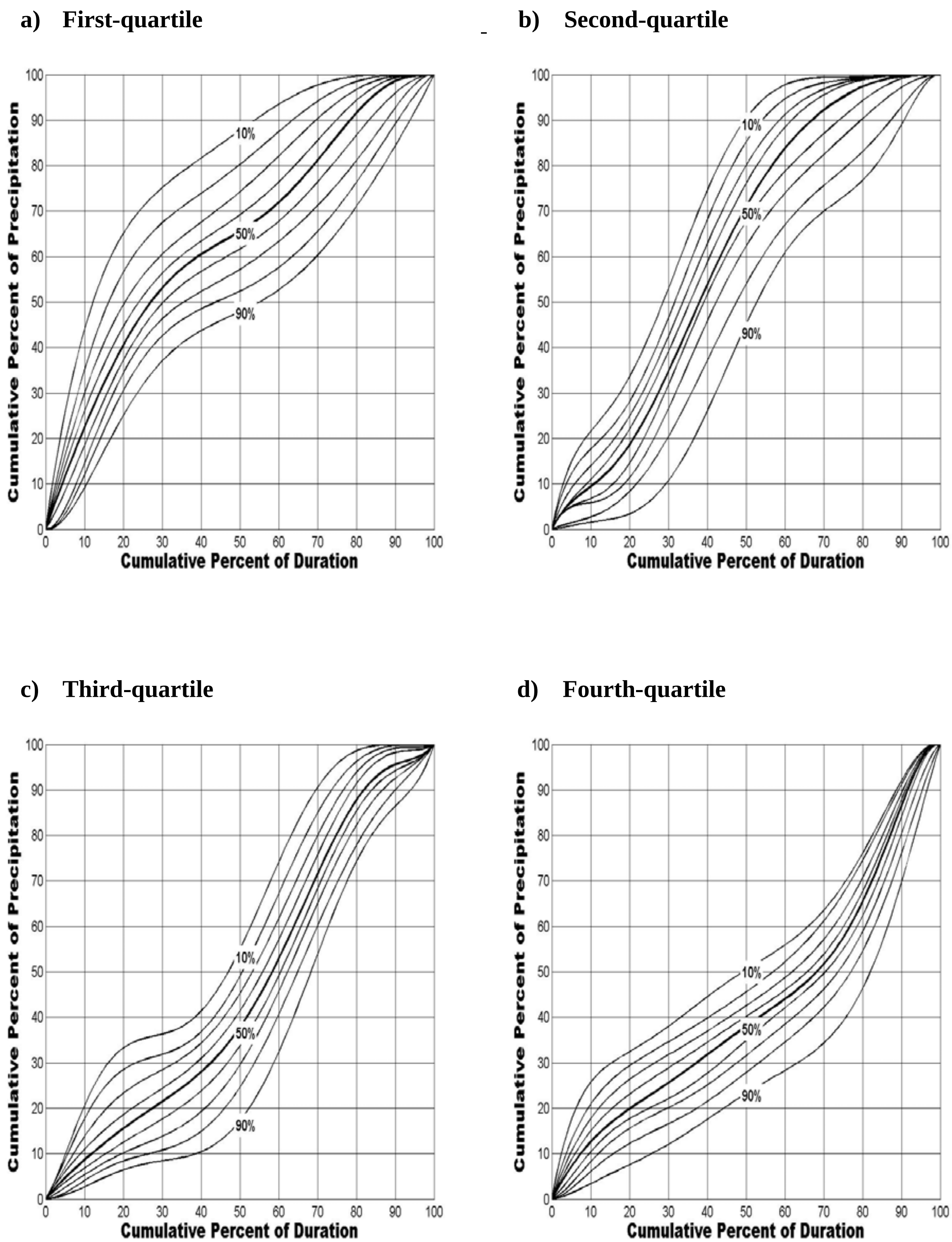


Figure A.6.6. 96-hour temporal distribution curves for region 13: a) first-quartile, b) second-quartile, c) third-quartile, and d) fourth-quartile cases.