Regional Precipitation Frequency Analysis for Wyoming

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Introduction

METSTAT is currently developing updated 6- and 24-hour precipitation frequency (PFE) estimates for the state of Wyoming. This project is part of a statewide Probable Maximum Precipitation (PMP) project lead by Applied Weather Associates that will provide a comprehensive analysis of extreme precipitation for the state of Wyoming. The results of the PFE analysis will serve an integral part of the orographic transpositioning procedure used in the PMP methodology, thereby improving the accuracy and reliability of the PMP results. Current PFEs for Wyoming are provided in NOAA Atlas 2, an outdated National Oceanic and Atmospheric Administration (NOAA) document published in 1973. Equally important, the updated PFEs will provide regulators and engineers a fundamental design criteria for numerous water management, small dam safety and hydrologic design projects.

METSTAT is utilizing a regional frequency analysis approach for computing PFEs with an average recurrence interval of up to 1,000 years. The approach is consistent with that used by the U.S. National Weather Service (NWS) Hydrometeorological Design Studies Center (HDCS) in developing NOAA Atlas 14 for other parts of the United States. Leveraging significant statistical and spatial interpolation advancements since NOAA Atlas 2, the new PFEs for Wyoming feature higher accuracy at a higher spatial resolution. This project provides an update of the 6- and 24-hour PFE contained in NOAA Atlas 2 Volume II published by the National Weather Service in 1973. See sample NOAA Atlas 2 PFE and station maps below.

Spatial Interpolation of MAMs

Since the mean annual maxima (MAM) values at stations serve as scaling factors to generate station-specific precipitation frequency estimates using RSCs, it is necessary to spatially distribute the annual maxima in order to derive spatially continuous precipitation frequency estimates. Interpolation of the MAM is the first critical step of the entire spatial interpolation process.

The sample size of the 06-hour mean annual maximum station database was considerably smaller (by a factor of 5) than for 24-hour duration and therefore down enough error of capturing the spatial details across Wyoming. Given the spatial interpolation of the mean annual maxima is largely governed by the station data, 360 06-hour “pseudo” stations were computed to anchor the 06-hour mean annual maxima in areas otherwise void of station data. The estimated 06-hour MAM at the “pseudo” stations were computed using a procedure similar to that implemented in NOAA Atlas 14.

Utilizing a relatively strong linear relationship between the square-root of MAP with the MAMs, the PRISM MAP grids, MAM grids were created. The analysis domain was divided up into MAP-vs-MAM regions so that statistically reliable (R² > 0.60) relationships could be attained in order to depict the varying relationship across the state. The same MAP-MAM regions were used for both the 06- and 24-hour durations.

Spatial Interpolation of PFEs

The spatial interpolation process began by regressing the gridded MAM value and the 2-year PFE at all station locations as shown in the flow chart. The resulting linear relationship provided a highly reliable function for computing the 2-year PFE from the MAM. To account for local variability in the linear function, residuals (observed minus function) were computed for each station. In order to infuse the influence of climate and promote a meaningful relationship of the residuals, the residuals were normalized by the MAM and spatially interpolated to a grid using an inverse distance squared algorithm (IDW, an exact interpolator). The normalized residuals were highly auto-correlated, so the IDW carried a good deal of skill in capturing spatial patterns. The normalized residual grid was then multiplied by the MAM grid to obtain a grid of actual residuals/adjustments, which added back to the initial 2-year grid resulted in a final 2-year PFE grid. In subsequent iterations, the 2-year PFEs became the predictor grid/variable for the 5-year PFEs, the 5-year for the 10-year, and so on. The end result was a suite of 6- and 24-hour PFE grids/maps for 2, 5, 10, 50, 100, and 1,000 year average recurrence intervals. Below are the final 100-year 6- and 24-hour PFE maps for Wyoming.

Comparison to NOAA Atlas 2

Differences between this project’s 100-year PFEs and those published in NOAA Atlas 2 were carefully considered. It was impossible to ascertain exactly what differences the product can so only speculate on why the new values differ. The NOAA Atlas 2 maps were hand-drawn based on a large degree of subjectivity, therefore making it difficult to associate differences to something specific. Differences could be the result of one or more of the following:

• Point statistical extrapolations (NOAA Atlas 2) vs. the more robust regional approach
• Higher spatial interpolation resolution, hence better definition among complex terrain.
• Long (>120 years) more robust database at stations
• More stations, especially in higher complex terrain

For this project, the statistical L-moment calculations were carried out in L-RAP, the L-moment Regional Analysis software developed by MGS Engineering Consultants, Inc. L-RAP conducted several tests on the stations’ MAMs and homogeneous regions before computing PFEs. The tests included:

• Heterogeneity Test – Indicated the level of heterogeneity among stations in a region.
• Goodness-of-ft Test – Determined which probability distribution (of 7) fit the data the best
• Discordancy Test – Identified stations whose MAMs was inconsistent from the region as a whole.
• Conversion factor – The conversion factors are independent of one and other.
• Stationarity Test – The MAMs must not have significant trends throughout the period of record.

Once the stations and regions passed all of the tests, the best-fitting probability distribution was used to compute Regional Growth (RGC) (shown to the right), which provided conversion factor for computing precipitation frequency estimates based on the individual station MAMs.

<table>
<thead>
<tr>
<th>Period of record (years)</th>
<th>NOAA Atlas 2</th>
<th>Precipitation</th>
<th>NOAA Atlas 2</th>
<th>Precipitation</th>
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<td>0</td>
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<td>200-500</td>
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Mean Annual Maximum

Consistent with the L-moment regional frequency analysis approach, the annual maxima series (AMS) was used as the basis for computing the all-season precipitation frequency estimates. AMS is the greatest precipitation amount for each 12-month period for a specified duration for a gauges’ period of record. For Wyoming, we utilized the water year, October 1st through September 30th, as the 12 month period from which AMSs were computed. Extreme precipitation events were extracted from the AMS, while the AMS and 24-hour annual maxima values were extracted from the hourly database for each from. The AMS, the mean annual maximum (MAM) was computed for each gauge.

The primary sources of precipitation gauge data for this study were the National Weather Service (NWS) Cooperative Observer Program’s (COOP) station data obtained from National Oceanic and Atmospheric Administration’s (NOAA) National Climatic Data Center (NCDC) and NCIOEL data obtained from the Natural Resources Conservation Service (NRCS). Both of these networks have been operating since the late 1800s and early 1970s respectively. The COOP data is collected and recorded daily. In addition, we utilized hourly reporting data from NCDC’s Hourly Precipitation Data set. 19th century daily precipitation data was acquired from the Climate Database Modernization Program (CDMP), which is working to preserve and digitize a wide range of U.S. daily weather observations from forts and other voluntary observers. Daily precipitation data for seven Wyoming forts were acquired and used. In general, the daily fort observations extended back to the 1860s to 1880s, but Fort Laramie extended back to 1849.

NOAA Atlas 2 was based on precipitation data collected through 1966, while this project includes precipitation data collected through 2010. This represents 44 years (more than double) additional data.

In fact, Table 1 and Table 2 illustrate the significant difference in gauge counts and record lengths between NOAA Atlas 2 and this analysis.

For the 100-year PFEs, the L-moment Regional Frequency Analysis method has demonstrated to produce robust, reliable precipitation frequency results. Instead of trying to define these smaller regions at the onset, large, generalized climate zones were created (shown below), then sub-divided into smaller, homogeneous L-moment regions for the 06- and 24-hr durations.

A homogeneous sub-region, in the context of a regional analysis, means the probability distribution of extreme events and their resulting frequency curves for at-site data are identical. Although regional statistics will describe the probability distribution, each at-site mean will be used as a scaling factor, thereby allowing spatial variability to occur among the sub-region.

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