

# Actuarial Weather Extremes Series

## California Precipitation December 30-31, 2022

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### Atmospheric River Impact Summary

In the last days of December 2022, an atmospheric river storm brought heavy rain and snowfall to many parts of California [1]. The storm system is ongoing as of 1/7/2023 and is expected to continue bringing heavy rain, flash flooding, and widespread road closures to many cities in the region.

According to NOAA, atmospheric rivers “are relatively narrow regions in the atmosphere that are responsible for most of the transport of water vapor from the tropics” [2]. The largest systems bring massive amounts of water vapor and strong winds that result in extreme rainfall and flooding. These rivers can affect the entire west coast of North America.

As reported by The Guardian [3], “the second highest daily rainfall total on record (5.46 inches) fell on December 31 in San Francisco. This total is more than 25% of the annual average rainfall, and only 0.08 inches short of the all-time record.” Governor Newsom declared a state of emergency as many towns and cities along the coast reported widespread damage and power outages [4].

### Data Sources

Two data sources were used in the following analysis: Automated Surface Observing System (ASOS) and Global Historical Climatology Network (GHCN). ASOS stations provide automated, hourly precipitation totals all across the world, typically at airports. GHCN is a curated data set of over 100,000 stations across the world, with published data undergoing quality review.

Detail analysis data can be found in Source [7] listed at the end of this report.

### Methodology

First, we looked at hourly precipitation data for all ASOS stations in California 12/29/2022-1/1/2023. Then, we identified three stations to examine in more detail, based on their total precipitation on 12/31/2022. For each of these stations, we retrieved all hourly observations available since 1990, although the first reporting date varied by station. Lastly, we calculated the maximum daily and hourly precipitation in each December in the historical record, resulting in Graphs 1 and 2 below.

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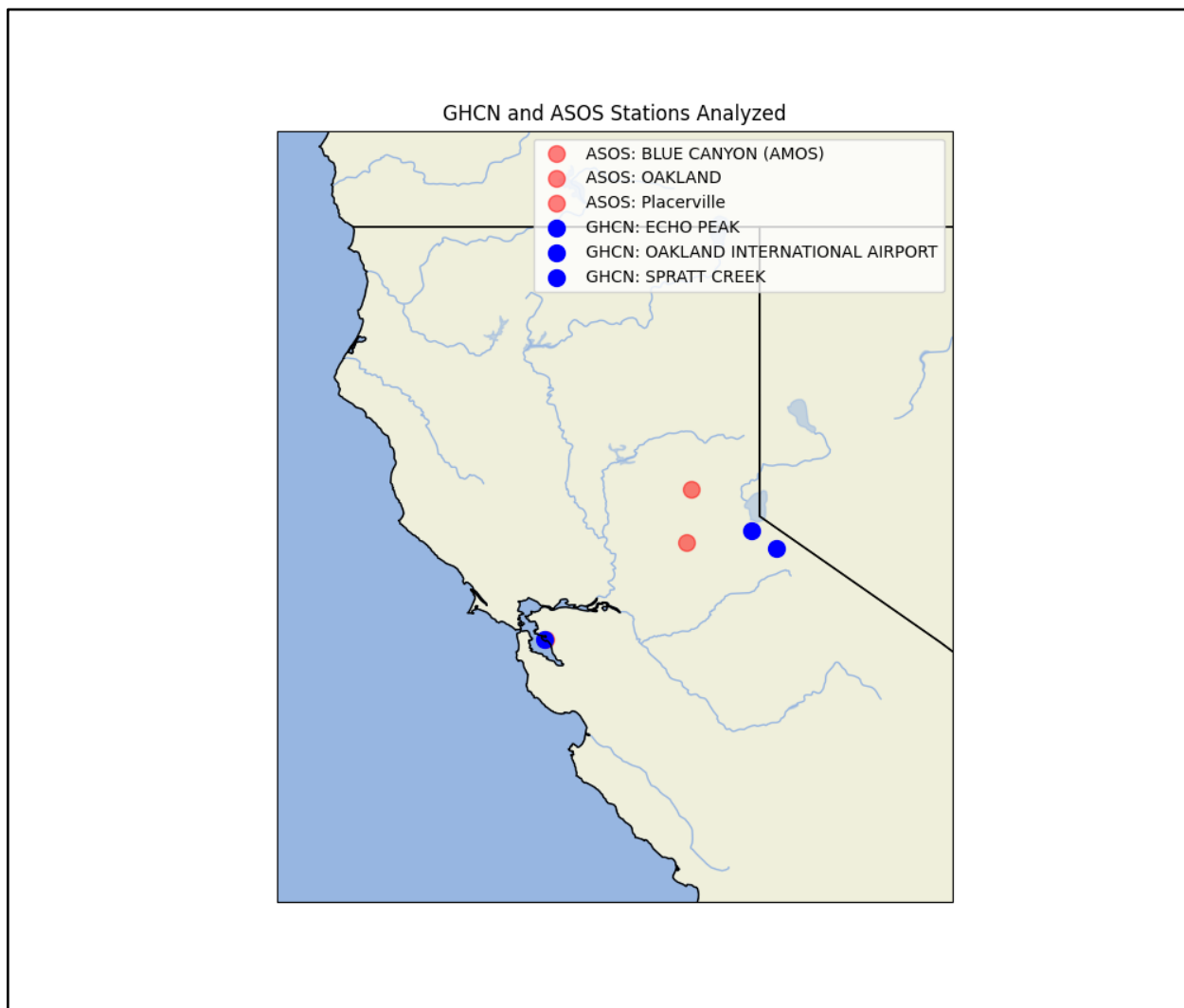
For the GHCN data, we followed a similar process to identify the maximum daily precipitation in each December in the historical record for three stations, resulting in Graph 3.

For more analysis on the ASOS data set, we began fitting various distributions to the Maximum Daily Precipitation observations in all months at the Blue Canyon station. Two of these distributions—Exponential and Power Series—are shown with the observations in Graph 4 below.

## Stations Analyzed

Figure 1 plots the six ASOS and GHCN stations referenced above and analyzed below.

**Figure 1**  
GHCN AND ASOS STATIONS ANALYZED



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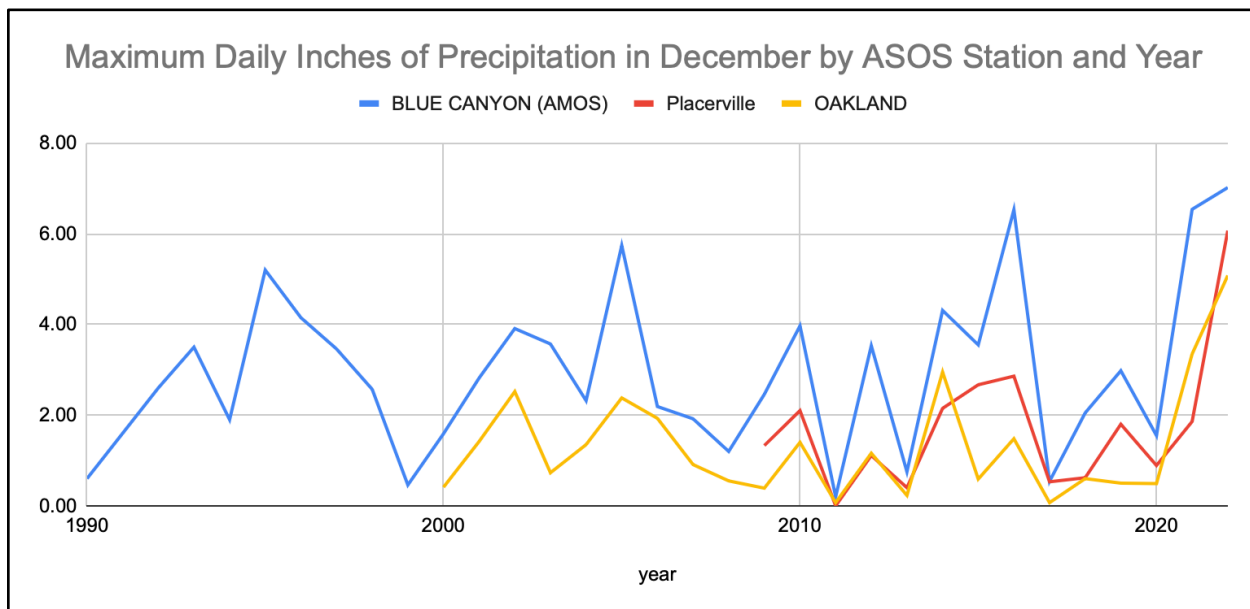
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## Results

Graph 1 shows the significant one-day precipitation totals observed in December 2022. For Placerville and Oakland, California, these totals are significantly above historical observations since 2009 and 2000, respectively [5].

### Graph 2

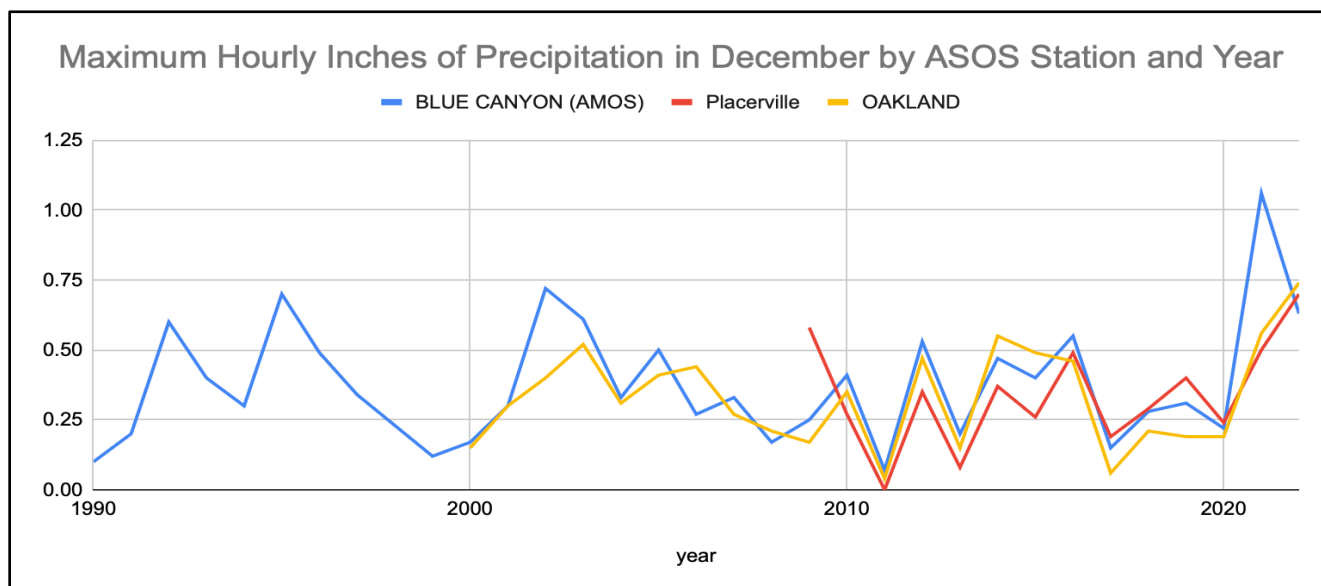
MAXIMUM DAILY INCHES OF PRECIPITATION IN DECEMBER BY ASOS STATION AND YEAR



Graph 2 shows similar results as Graph 1 above, although the 2022 observations appear less extreme for hourly maximums [5].

### Graph 2

MAXIMUM HOURLY INCHES OF PRECIPITATION IN DECEMBER BY ASOS STATION AND YEAR

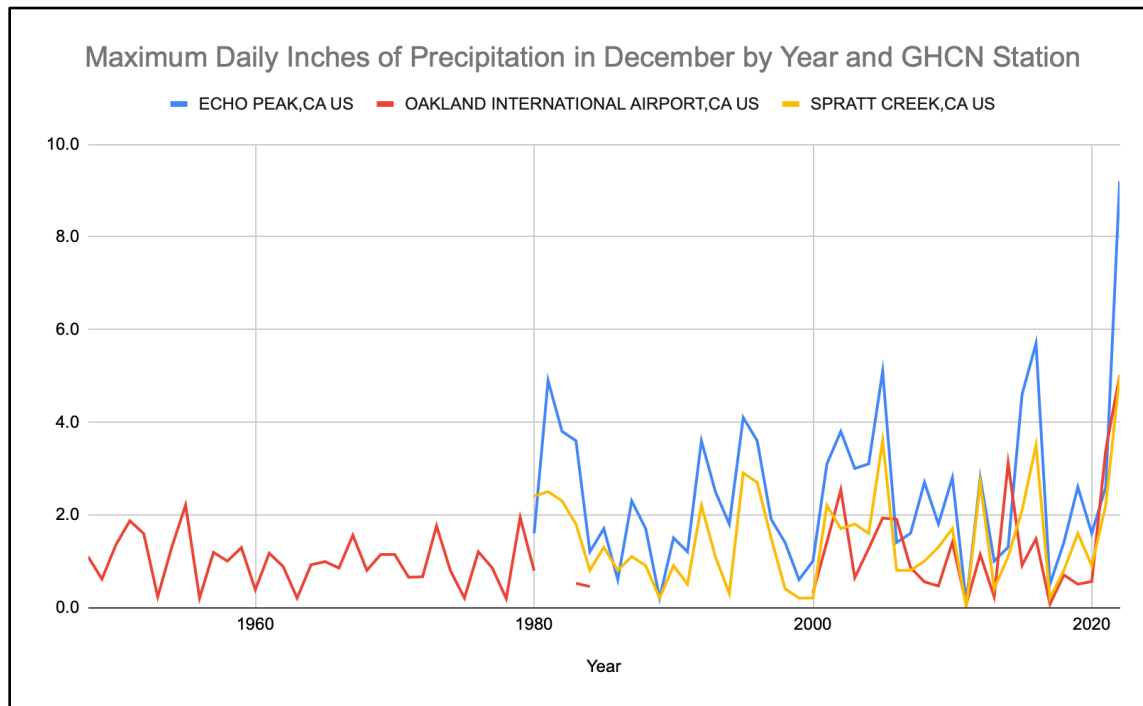


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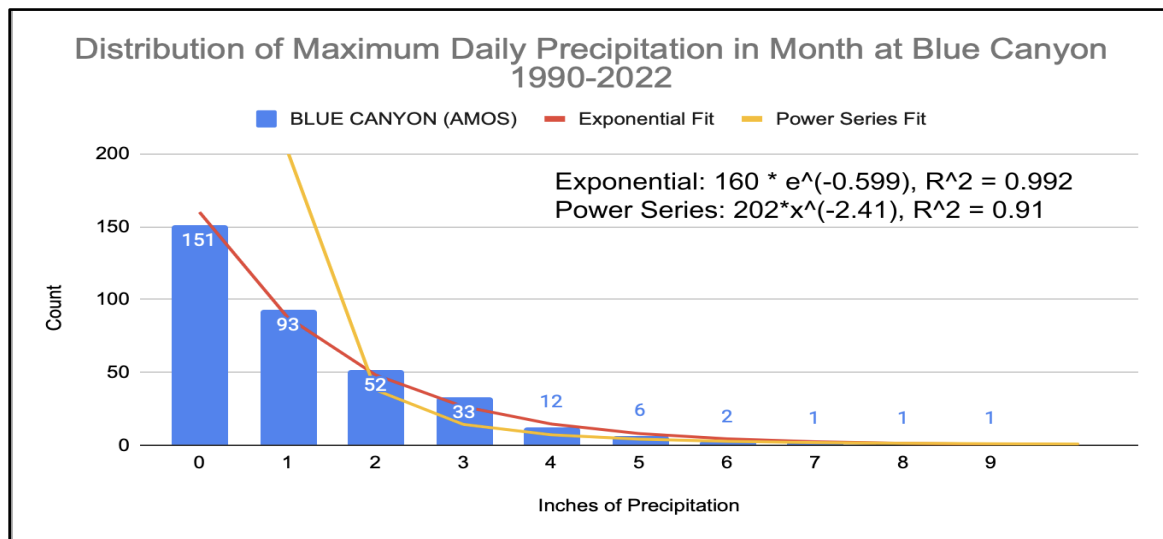
Graph 3 shows a similar analysis as Graph 1 above, using the GHCN stations [6]. All three stations hit daily records, with Echo Peak receiving a one-day 1.5x the previous maximum.

**Graph 3**  
 MAXIMUM DAILY INCHES OF PRECIPITATION IN DECEMBER BY YEAR AND GHCN STATION



Graph 4 shows the results of fitting the Maximum Daily Precipitation Total at the Blue Canyon Station to an Exponential Distribution and a Power Series Distribution.

**Graph 4**  
 DISTRIBUTION OF MAX DAILY PRECIPITATION IN MONTHS AVAILABLE FROM 1990-2022 AT BLUE CANYON STATION



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Table 1 below shows the actual observations by bucket and the projected values under each distribution. From the R<sup>2</sup> values in Graph 4, we see that the Exponential distribution has a better overall fit. However, Table 1 indicates that the Power Series distribution results in smaller variances for the larger, more extreme buckets, with the small exception of the 8–9-inch bucket.

**Table 1**  
**DAILY DECEMBER OBSERVATIONS: ACTUAL AND UNDER EXPONENTIAL AND POWER SERIES DISTRIBUTIONS**

Bucket	BLUE CANYON	Function Fit		Variance	
		Exponential Fit	Power Series Fit	Exponential	Power Series
0-1	151	160		9.00	-151.00
1-2	93	87.90	202.00	-5.10	109.00
2-3	52	48.29	38.01	-3.71	-13.99
3-4	33	26.53	14.31	-6.47	-18.69
4-5	12	14.57	7.15	2.57	-4.85
5-6	6	8.01	4.18	2.01	-1.82
6-7	2	4.40	2.69	2.40	0.69
7-8	1	2.42	1.86	1.42	0.86
8-9	1	1.33	1.35	0.33	0.35
9+	1	0.73	1.01	-0.27	0.01

From an actuarial modeling perspective, these results raise an interesting consideration of distribution selection. As with most models, the selection will center on what exactly the actuary is trying to model: all observations or the extreme observations? While this analysis focused on one station’s history with few observations in the extreme buckets and any conclusions are therefore limited, it does emphasize the actuary’s responsibility to focus on the model’s purpose at all phases of analysis.

**Sources**

- **[1] Heavy rain and snow falls across California in atmospheric river storm**
  - National Public Radio
  - <https://www.npr.org/2022/12/31/1146443609/california-storm-rain-snow-floods-landslides>
  - Date Published: 12/31/2022
- **[2] Atmospheric Rivers**
  - National Oceanic and Atmospheric Administration
  - <https://www.weather.gov/media/ajk/brochures/Alaska%20Atmospheric%20River.pdf>
  - Date Accessed: 1/8/2023

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- **[3] San Francisco has second rainiest day on record**
  - The Guardian
  - <https://www.theguardian.com/environment/2023/jan/02/weather-tracker-san-francisco-hit-by-second-rainiest-day-on-record>
  - Date Accessed: 1/9/2023
- **[4] California declares state of emergency**
  - The Guardian
  - <https://www.theguardian.com/us-news/2023/jan/04/california-bomb-cyclone-storm-flooding>
  - Date Accessed: 1/9/2023
- **[5] ASOS Precipitation Totals**
  - Automated Surface Observing System (ASOS): Iowa State Mesonet
  - [https://mesonet.agron.iastate.edu/request/asos/hourlyprecip.phtml?network=CA\\_ASOS](https://mesonet.agron.iastate.edu/request/asos/hourlyprecip.phtml?network=CA_ASOS)
  - Date Accessed: 1/7/2023
- **[6] GHCN Precipitation Totals**
  - Global Historical Climatology Network
  - <https://www1.ncdc.noaa.gov/pub/data/ghcn/daily/>
  - Date Accessed: 1/7/2023
- **[7] Source Data Analysis**
  - [202303 West Coast Rain and Floods](#)
  - Date Created: 1/7/2023
  - This Google Sheet is available to the public via the link.

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