Hydrometeorological Design Studies Center
Progress Report for Period
1 January to 31 March 2024

Office of Water Prediction
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Silver Spring, Maryland

April 30, 2024

DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various tasks associated with these projects. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any other purpose does so at their own risk.

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I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the Office of Water Prediction (OWP) of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) updates precipitation frequency estimates for parts of the United States and affiliated territories, in coordination with stakeholder requests. Updated precipitation frequency estimates, accompanied by additional relevant information, are published as NOAA Atlas 14 and are available for download from the [Precipitation Frequency Data Server (PFDS)](#).

NOAA Atlas 14 is divided into volumes based on geographic sections of the country and affiliated territories. Figure 1 shows the states or territories associated with each of the volumes of the Atlas. To date, precipitation frequency estimates have been updated for AZ, NV, NM, UT (Volume 1, 2004), DC, DE, IL, IN, KY, MD, NC, NJ, OH, PA, SC, TN, VA, WV (Volume 2, 2004), PR and U.S. Virgin Islands (Volume 3, 2006), HI (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), CA (Volume 6, 2011), AK (Volume 7, 2011), CO, IA, KS, MI, MN, MO, ND, NE, OK, SD, WI (Volume 8, 2013), AL, AR, FL, GA, LA, MS (Volume 9, 2013), CT, MA, ME, NH, NY, RI, VT (Volume 10, 2015), and TX (Volume 11, 2018).

HDSC is currently working on two NOAA Atlas 14 Volumes: Volume 12 and Volume 13, and initiated Atlas 15 development. The Volume 12 project area covers the states of Idaho, Montana and Wyoming, while the Volume 13 project area covers the states of Delaware, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia and Washington D.C. and approximately a 1-degree buffer around these states.

Figure 1 shows the new and updated project areas included in NOAA Atlas 14, Volumes 1 to 13. The proposed schedules for the two projects are contingent on funding and a timely hiring process. For any inquiries regarding NOAA Atlas 14, please email hdsc.questions@noaa.gov.

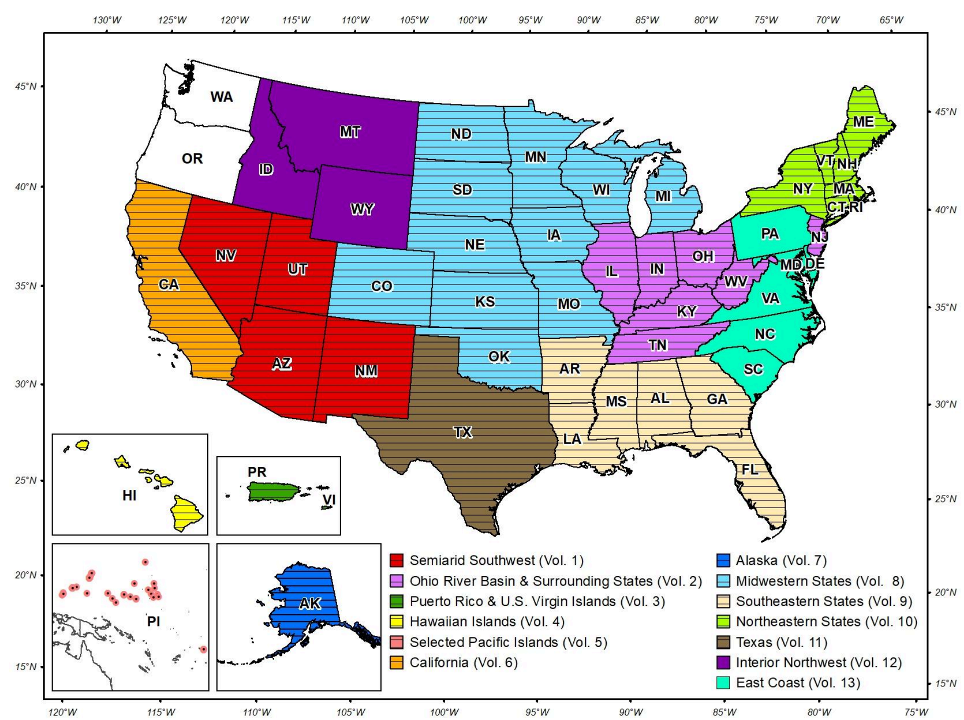

Figure 1. States or territories associated with each of the volumes of the Atlas.

II. CURRENT NOAA ATLAS 14 PROJECTS

1. VOLUME 12: INTERIOR NORTHWEST

On May 26, 2021, the HDSC commenced work on a NOAA Atlas 14 Volume 12. The precipitation frequency estimates for this volume include the states of Idaho, Montana, and Wyoming, with an approximately 1-degree buffer around these states (Figure 2). The expected project's completion date for this volume is summer of 2024.

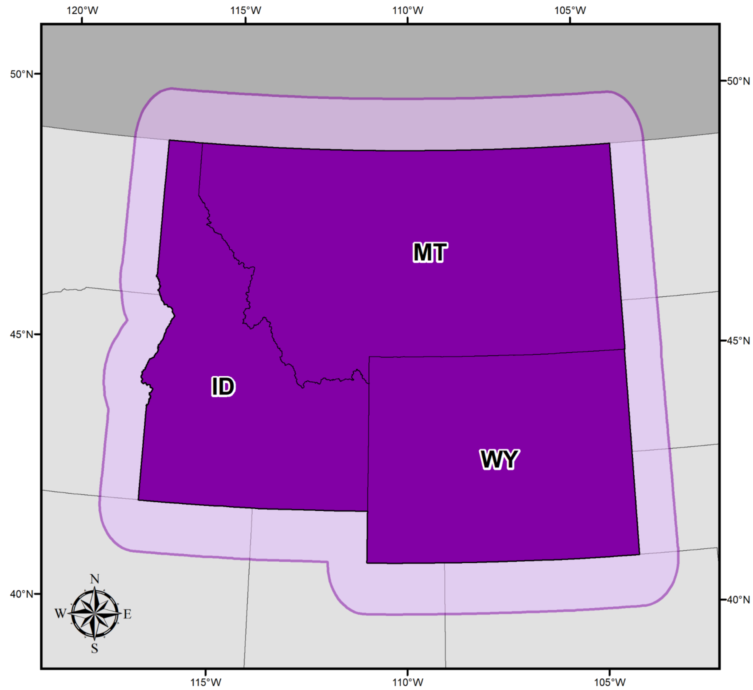

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of January 1 to March 31, 2024, we compiled the received feedback from the peer review and addressed it. In addition, in this reporting period, we implemented additional changes for mean annual maxima grids development across all durations with the help of the Oregon State University, PRISM group. We updated all the datasets and completed the final quality control task for all datasets for all durations 1-day through 60-day. For more information on how the quality control tasks are performed, please refer to July - Sept, 2023 Progress Report.

1.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2024)

For the sources of datasets considered, contacted, downloaded or formatted for the precipitation frequency analysis for NOAA Atlas 14 Volume 12, please see July - Sept, 2022 Progress Report.

1.1.1. AMS QC for longer durations and appended data years

Since AMS data at both high and low extremities can considerably affect precipitation frequency estimates, they need to be carefully investigated and either corrected or removed from the AMS if due to measurement errors. In this reporting period, we completed work on the final quality control task for daily durations 1-day through 60-day. In total there were over 833 simple corrections and 92 special corrections.

1.1.2. Peer review

During this reporting period, we consolidated all comments, reviewed them and we started to address them accordingly and to respond to reviewers. The (anonymous) reviewers' comments with our responses and resulting actions will be published as an Appendix 4 in the Volume 12 document.

We received comments from 10 reviewers. Some reviewers commented on inconsistencies relative to expected spatial patterns especially in the mountains for 100-year precipitation frequency estimates at sub-daily durations. During this reporting period, we investigated the causes and ways to mitigate this effect for the final grids. We reviewed information at co-located daily and hourly stations with shorter records and re-examined AMS data at selected stations in station-dense areas. Follow-up decisions about stations' exclusions or revisions were done on a case by case basis.

Since we use regional frequency analysis approach to support estimation of the frequencies of rare events by using data from several stations to calculate estimates at one station, we also revisited regions defined before the peer review to accommodate the addition and deletion of stations and to investigate if additional modifications were needed to improve the spatial smoothness and reliability of estimates in mountainous regions.

1.1.3. Trend Analysis

The precipitation frequency analysis methods used in NOAA Atlas 14 assume that annual maximum series (AMS) data used in the analysis are stationary. Several parametric and non-parametric statistical tests have been used for the detection of trends in AMS mean and variance. These include the parametric *t*-test, non-parametric Mann-Kendall test, and Levene's test.

In this reporting period, the codes used to perform these statistical tests for trend analysis were updated and run on AMS data used to calculate the preliminary precipitation frequency estimates for Volume 12 peer review. These initial results were similar to previous Atlas 14 volumes. Any action regarding the assumption of stationary AMS will be determined based on upcoming results using finalized AMS data.

1.1.4. Temporal distributions and seasonality

Temporal distributions

The Natural Resources Conservation Service has developed curves that are commonly used in engineering design to describe the temporal distribution of rainfall. For NOAA Atlas 14, NWS has adopted a technique for describing the many potential temporal distributions of natural rainfall in probabilistic terms; the technique is described in more detail in Appendix 5 of Volume 11 document.

Temporal distributions of precipitation amounts exceeding precipitation frequency estimates for the 2-year ARI have been calculated for 6-hour, 12-hour, 24-hour, and 96-hour durations for three climate regions delineated for this project area based on characteristics of heavy precipitation. They will be expressed in probability terms as cumulative percentages of precipitation totals and will be provided as charts and in tabular format.

Seasonality

To portray the seasonality of extreme precipitation throughout the project area, annual maxima that exceeded precipitation frequency estimates (quantiles) with selected annual exceedance probabilities (AEPs) for chosen durations were examined for the two climate regions delineated for Volume 12. In this reporting period, the codes used to perform this analysis were updated and run on AMS data used to calculate the preliminary precipitation frequency estimates for Volume 12 peer review. The analysis will be repeated using finalized AMS data, and graphs showing the monthly variation of the exceedances for a region will be provided for each location in the project area via the Precipitation Frequency Data Server (PFDS).

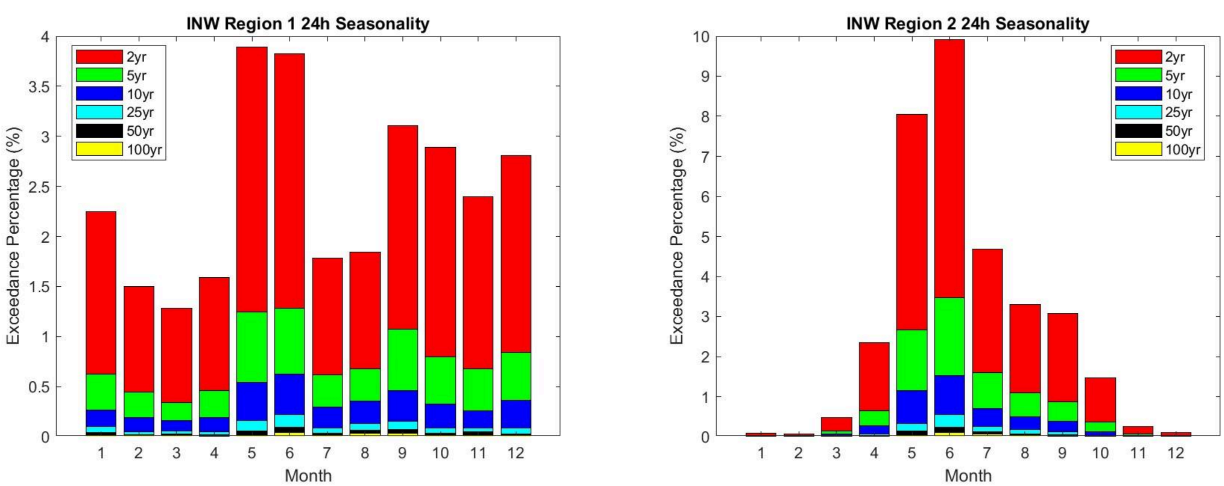

Figure 3. Preliminary seasonal exceedance graphs for the Northern US Rockies (region 1) and Northern Great Plains (region 2) for the 24-hour duration.

1.1.5. Confidence intervals

The Monte Carlo simulation procedure was employed to estimate the 90% confidence intervals for AMS-based regional precipitation frequency estimates, adhering to the methodology described by Hosking and Wallis (1997). A concise outline of the procedure is provided below. For each region, 1000 realizations were generated in such a way as to reflect the specific characteristics of the data from which the regional precipitation frequency estimates were derived. Each realization has the same number of sites, record length at each site and regional average L-moment ratios based on the observed data. Also, the inter-station dependence is accounted for in generating the realizations. For each realization, the simulated regional precipitation frequency estimates are calculated similarly to the regional precipitation frequency estimates of the observed data.

The simulated estimates were sorted from smallest to largest and the 50th value was selected as the lower confidence limit, while the 950th value was selected as the upper confidence limit. It should be noted that confidence intervals constructed through this approach account for uncertainties in distribution parameters but not for other sources of uncertainties (for example, distribution selection) that could also significantly impact the total error, particularly at more rare frequencies.

The legacy MATLAB code for estimating the confidence intervals is translated to Python and updated to analyze the Volume 12 data. A GUI is being developed to visualize the precipitation frequency estimates with confidence intervals. The analysis will be repeated using finalized AMS data.

1.1.6. Digitized stations

In areas of high importance or scarce data, additional precipitation data were digitized to improve analysis by extending record lengths and/or including extreme events missing in digitized datasets. The additional digitized data were collected from the NCEI CDMP dataset and consist mainly of data from Climate Records Books (daily) and the original COOP observer forms (daily). In many cases, the highest extracted annual maxima came from the digitized periods. The increase in record from digitization varies from station to station, but increased by as much as 49 additional years at Pocatello, ID.

Figure 4. The locations of stations where daily records were extended through digitization.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - Jun 2024)

During the next reporting period, we will work on completing the final gridded AMS-based and partial duration series (PDS)-based estimates, as well as gridded upper and lower confidence limits for 90% confidence interval for all durations and frequencies, creating cartographic maps, documentation, and web publication.

1.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [Completed]
- Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging)] [Completed]
- Regionalization and frequency analysis [Completed]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Completed]
- Peer review [Completed]
- Revision of PF estimates [CY Q2 2024; In Progress]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [CY Q2 2024]
- Web publication [Summer 2024]

2. VOLUME 13: EAST COAST STATES UPDATE

On July 28, 2022, the NOAA Atlas 14 Volume 13 kickoff meeting was held to commence work on a new NOAA Atlas 14 Volume 13. The precipitation frequency estimates for this volume include the states of Delaware, Maryland, North Carolina, Pennsylvania, South Carolina, Virginia and Washington D.C. and approximately a 1-degree buffer around these states (Figure 7). This project's expected completion date is December 2025, subject to change based on the availability of funds and personnel to support the development of two volumes.

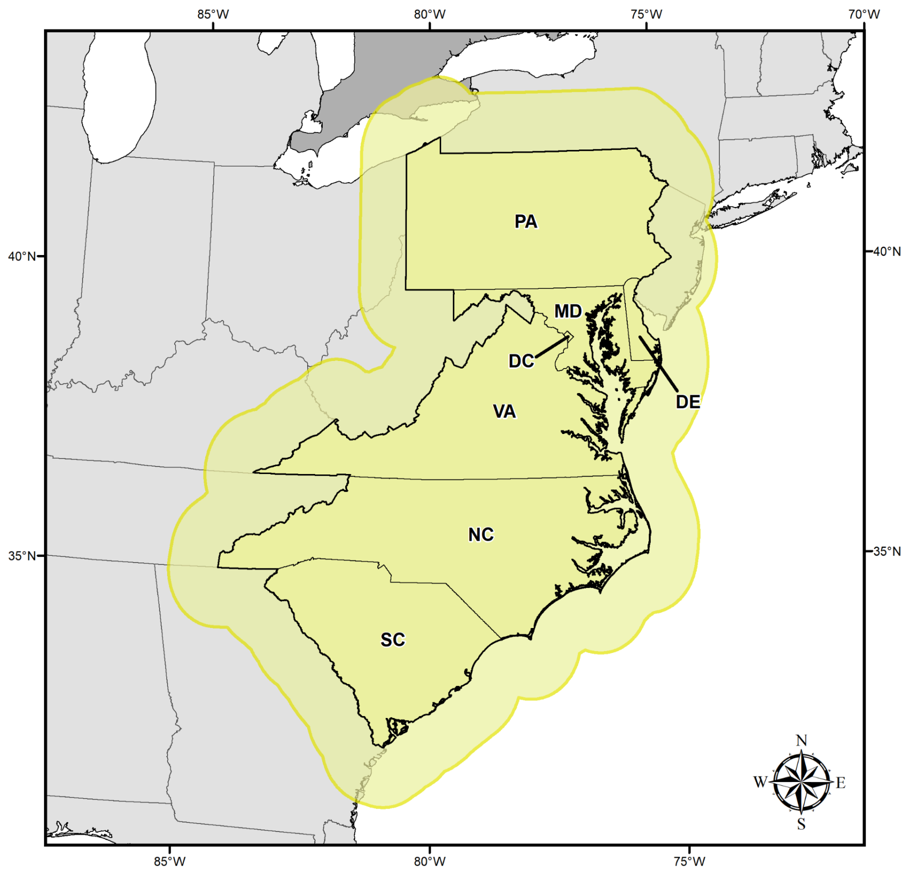

Figure 7. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2024)

In the reporting period of January 1 to March 31, 2024, we completed the modernization of the station cleanup software and initiated the manual station cleanup for the co-located NCEI networks. In addition, we continue quality controlling the station metadata and high outlier checks. Finally, we continue investigating the development of the mean annual maxima grids for this project area.

2.1.1. Data collection and data screening

During the January 1 to March 31, 2024 reporting period, we continue to format and quality control the identified precipitation networks that are considered for the development of the Atlas 14 Volume 13 estimates. As with all NOAA Atlas 14 Volumes, the primary source of data is the NOAA's National Centers for Environmental Information (NCEI). The NCEI is the most reliable data source network in the United States. The NCEI's precipitation data alone may not be sufficient to support the objectives of NOAA Atlas 14. Since the NOAA Atlas 14 estimates are based on the statistical analysis of the historical record of the observed precipitation data, denser spatial coverage may be needed to compute the robust and reliable precipitation frequency estimates. Therefore, for each project area, we also collect digitized data measured at 1-day or shorter reporting intervals from other Federal, State and local agencies.

Table 2. Sources of datasets considered, contacted, downloaded or formatted for the precipitation frequency analysis for NOAA Atlas 14 Volume 13.

FID	Data Provider	Dataset name	Abbr.	Status
1	National Centers for Environmental Information (NCEI)	Automated Surface Observing System	ASOS	Formatted
2		DSI 3240, DSI 3260	DSI 3240 DSI 3260	Formatted
3		Global Historical Climatology Network	GHCNd	Formatted
4		Environment Canada	GHCNd	Formatted
5		Integrated Surface Data (Lite)	ISD_LITE	Formatted
6		Local Climatological Data	LCD	Formatted
7		Coop Hourly	GHCNh	Formatted
8		United States CoCORAHS	GHCNd	Formatted
9		Canada CoCORAHS	GHCNd	Formatted
10		Weather Bureau Army Navy (WBAN)	GHCNd	Formatted
11		U.S. Climate Reference Network	USCM	Formatted
12	Aberdeen Proving Ground	Phillips Airfield Weather Station	PAWS	Formatted
13	Hampton Roads Sanitation District		HRSD	Received
14	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	Formatted
15	National Weather Service (NWS) Mid-Atlantic River Forecast Center (MARFC)	Integrated Flood Observing and Warning System	IFLOWS	Formatted
16	National Oceanic and Atmospheric Administration (NOAA)	National Estuarine Research Reserve	NERRS	Formatted
17	National Atmospheric Deposition Program (NADP)	National Trends Network	NADP	Formatted
18	North Carolina State University, State Climate Office (NCSU)	North Carolina Environment & Climate Observing Network	ECONet	Formatted
19	Tennessee Valley Authority (TVA)	Rainfall Gauge Data	TVA	Formatted
21	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network	RAWS	Formatted
22	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network	SCAN	Formatted
24	University of Albany	New York State Mesonet	NYS	Formatted
25	University of Delaware, Center for Environmental Monitoring & Analysis	Delaware Environmental Observing System	DEOS	Formatted
26	University of Georgia	Georgia Weather Network	GWN	Formatted

FID	Data Provider	Dataset name	Abbr.	Status
27	Western Kentucky University	Kentucky Mesonet	KYM	Formatted

The following datasets were not used after investigation and review of periods of record and data quality: Automatic Position Reporting System WX NET/Citizen Weather Observer Program, Synoptic Weather, Maryland Department of Transportation Road Weather Network, Pennsylvania State University Environmental Monitoring Network, and WeatherSTEM.

2.1.2. Station metadata screening

In this reporting period, we continue to perform manual metadata inspection for datasets formatted (Table 2). All NCEI datasets have been prescreened using the Python-based software that has been developed to modernize and automate our station metadata quality control process.

The approach outlined here has been used to identify stations that need to be manually inspected. For each station, the difference between DEM and station metadata was calculated and flagged if greater than 10 meters (32.8 ft). A 3-minute search box is centered on each station to identify the elevation range within the surrounding area. This elevation range is used to determine both the final error threshold and the final size of the precision box.

- Error threshold: The threshold is set equal to either the elevation range within the 3-min search area or 150 meters (492 ft), whichever is smaller.
- Precision box: If the elevation range within the 3-min search area is equal to or greater than 500 meters (1,640 ft), indicating a region of complex terrain, the 3-min search area is replaced with a smaller 1-min precision box. Otherwise, the region is considered to be relatively flat, and the larger 3-min search area is used as the precision box (see Figure 8).

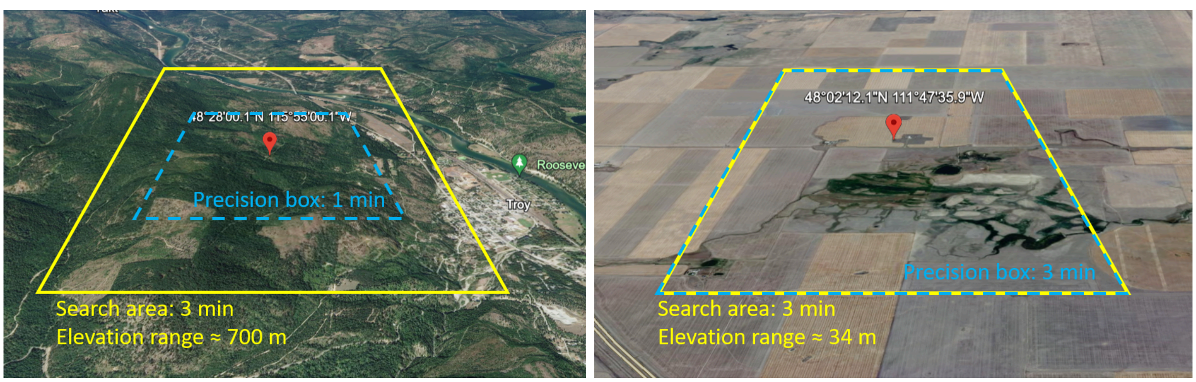

Figure 8. Examples of elevation ranges identified within 3-minute searches resulting in the implementation of 1-minute and 3-minute precision boxes.

Once the final error thresholds and precision box sizes are identified, stations where the difference between DEM and station metadata are larger than the error threshold and the station metadata elevation values were not found within DEM elevation range of the precision box, were flagged for manual inspection.

2.1.3. Station cleanup

In this reporting period, we initiated the first round of cleanup for the colocated NCEI datasets, using the station cleanup visualization dashboard software, documented in the previous October - December, 2024 QPR Report.

Station cleanup investigation involves reviewing time series plots of annual maxima for 1-hour, 12-hour 1-day, 2-day and 60-day durations for multiple stations that are co-located. If the station with a shorter reporting interval provides the same information as a longer reporting interval, then the station with the longer reporting interval is removed. If the station with the longer reporting interval has a longer period of record, then it was retained in the dataset in addition to the co-located station with the shorter reporting interval. Where appropriate, we identify data from stations recording at shorter intervals to extend records or to fill in gaps in records for collocated stations recording at longer intervals. Stations with the same reporting interval but recording different time periods are merged together to create longer time series. In this reporting period, a total of 794 locations were reviewed, 244 stations were merged, and 705 stations were deleted.

The example below shows the co-location of NCEI-related gauges with the same COOP ID of “091908” for “CHICKAMAUGA PARK LARC, GA” (Figure 9).

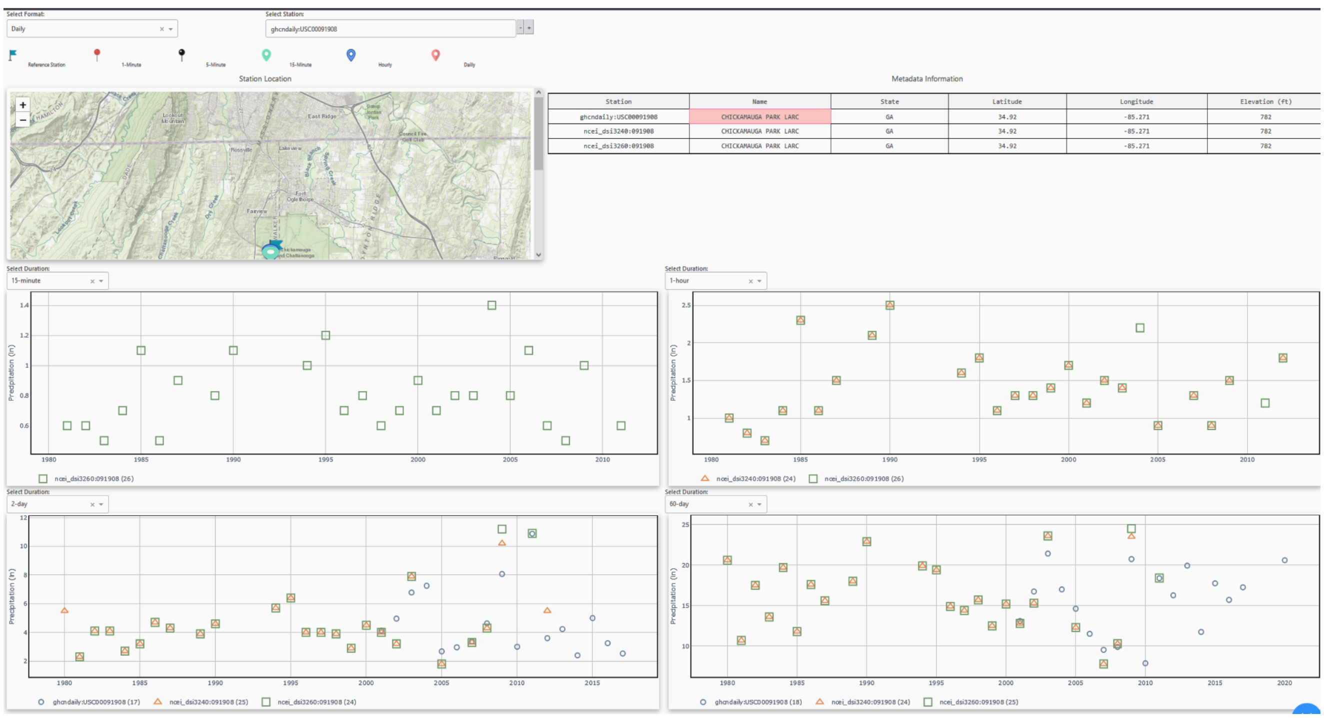

Figure 9. Co-located cleanup software, showing a location with a 15-minute, 1-hour, and 1-day timestep gauge, with varying periods of record and annual maxima.

For this example, we focus on the annual maxima differences for the year 2009, where sub-daily versions of this gauge (measured by an automated gauge) are significantly different at the 1-day (and other durations not pictured) aggregated duration compared to the manually measured daily gauge (Figure 10).

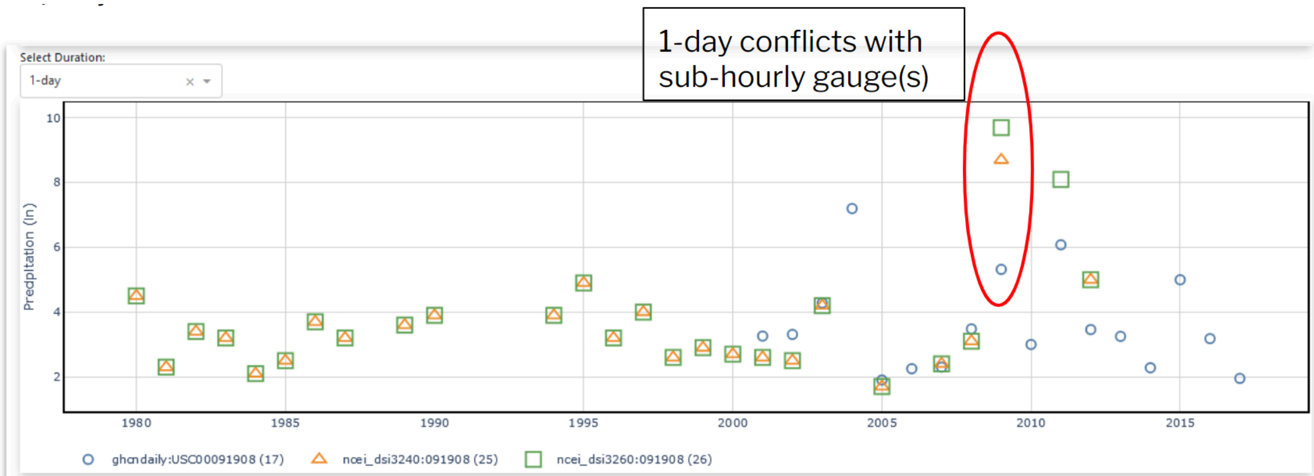

Figure 10. Co-located cleanup software, showing different annual maxima for sub-daily versus daily during 2009. The timesteps for GHCN Daily:USC00091908, DSI 3240:091908, DSI 3260:091908 are 1-day, 1-hour, and 15-minute, respectively.

We can examine several artifacts, including the Cooperative Observations (COOP) form for the daily data, storm reports, and multisensor radar/gauge blended estimates (Figure 11). It was determined that the daily observations were not recorded during a confirmed flash flood event overnight on September 20-21, 2009. The automated 15-minute/1-hour gauges properly measured this event, and were consistent with storm reports and multisensor precipitation estimates. The software merges and ensures that the proper annual maximum is retained for the 1-day (and other daily) durations for precipitation frequency statistics.

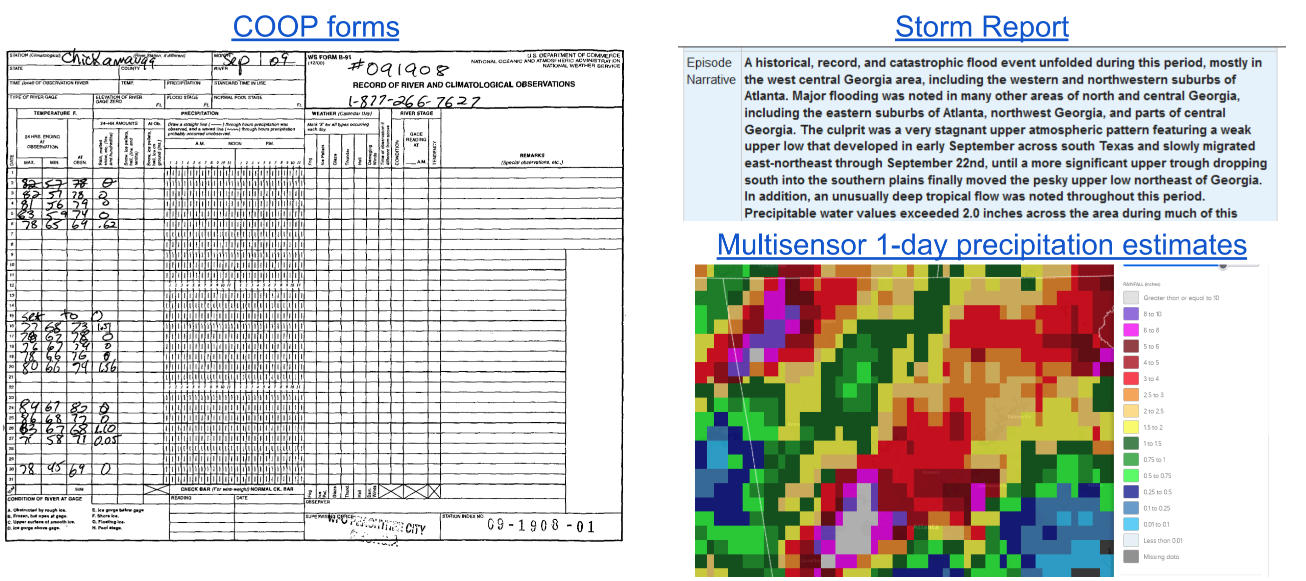

Figure 11. COOP form, storm data, and 1-day multisensor precipitation estimates to assist in quality assurance / quality control for the annual maxima discrepancy during 2009.

2.1.4. Investigating spatial covariates

During this reporting period, we continue to explore in-house development of the mean annual maxima (MAM) grids for the spatial interpolation within this project area. Using stepwise multiple regression, we are attempting to determine the most critical covariates in this project area based on mean squared error and R^2 to derive the mean annual maxima grids that we can then use to interpolate at-station regional estimates to 30-arc sec grids, following the NOAA Atlas 14 interpolation process.

For this analysis, we have identified several different spatial covariates, belonging to three different categories static variables, taken directly from source datasets: elevation, slope, aspect, latitude, longitude, and distance to coast; derived, based on the journal publications: southness, eastness, height above local terrain, and nearby surface water proportion (a.k.a. "lake effect index"); and model/climatology based, such as PRIMS mean annual precipitation, and NCAR's CONUS404 MAM, etc.

Initial analysis, selects 7 of 11 covariates, including NCAR'S CONUS404 mean annual maxima grids. Using stepwise multiple regression with residual error correction via ordinary kriging, this initial analysis, produced $R^2 \approx 0.90$, error standard deviations are ± 6-7% over Volume 13 area for 1-day duration. In the next reporting period, we will continue evaluating spatial covariates selected and will extend an analysis on other durations.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - Jun 2024)

We will continue with data collection, reformatting, and data quality checks for NCEI stations. In parallel, we will continue to evaluate the spatial covariates, and will start investigating the regionalization approach for this project area.

2.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [Revised to Q2 2024; In Progress]
- Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, independence, consistency across durations, duplicate stations, candidates for merging)] [Q2 2024; In Progress]
- Regionalization and frequency analysis [Q3 2024; In Progress]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [CY Q3 2024; In Progress]
- Peer review [CY Q4 2024]
- Revision of PF estimates [CY Q3 2025]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [CY Q4 2025]
- Web publication [CY Q4 2025]

III. ATLAS 15: PRECIPITATION FREQUENCY STANDARD UPDATE

NOAA has received federal funding under the Bipartisan Infrastructure Law to revise and update precipitation frequency estimates nationwide to account for temporal nonstationarity and the integration of future climate projections. Once completed, this update will be known as NOAA Atlas 15 and will provide civil engineers and other design professionals with consistent, high quality, authoritative rainfall estimates that have continuous spatial coverage across the U.S. and affiliated territories. For more information on the initiation of Atlas 15 development, please refer to July - Sept, 2023 Progress Report.

A technical kickoff meeting was held on July 10, 2023, to bring together the dedicated teams working towards achieving project milestones. In this reporting period, the Atlas 15 team continues development work, including collecting and formatting the datasets that will be used to develop estimates for the contiguous United States, enhancing the statistical nonstationary maximum likelihood approach, and evaluating available climate model datasets for this application.

Below are some of the key work streams supporting the development and implementation of Atlas 15:

- [Contract and Grant] Enhance Atlas 15 Framework (methodology refinements beyond baseline)
- [Contract] Establish Atlas 15 Data Repository
- [Contract] Apply Automated and Manual Quality Control to Precipitation Observations
- [Contract and Grant] Evaluate Climate Model Outputs for Atlas 15 Application
- [Contract] Generate Atlas 15 Precipitation Frequency Estimates
- [Contract and Grant] Develop an Atlas 15 Website and Data Dissemination Solution

For more information on the timeline for the development and deployment of updated authoritative Atlas 15 precipitation frequency estimates nationwide, please refer to the Atlas 15 Flyer.

IV. OTHER

1. CONFERENCES

The OWP team has been keeping various stakeholders updated on the progress of the Atlas 15 project. In this reporting period, OWP Sandra Pavlovic, CIROH Program Manager Debbie Martin, and CIROH Climate Lead Dr. Ken Kunkel presented three presentations at the 104th American Meteorological Society Annual Meeting which took place from 28 January to 1 February 2024 in Baltimore, Maryland.

Fernando Salas, Director of the Geo-Intelligence Division, National Water Center, NOAA/National Weather Service, and Sandra Pavlovic, HDSC Program Lead presented the USACE Silver Jackets webinar titled NOAA Atlas: Planned Updates to the Nation's Precipitation Frequency Estimates on February 27, 2024.