Hydrometeorological Design Studies Center
Progress Report for Period
1 October to 31 December 2024

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

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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.

TABLE OF CONTENTS

I. INTRODUCTION

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), TX (Volume 11, 2018), and ID, MT, WY (Volume 12, 2024).

OWP is currently working on Volume 13. 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. For any inquiries regarding NOAA Atlas 14, please email hdsc.questions@noaa.gov.

The OWP is developing and implementing NOAA Atlas 15, the future authoritative source and national standard for precipitation frequency information. For more information on the NOAA Atlas 15 development, please visit the NOAA Atlas 15 Informational Page or email us at atlas15.info@noaa.gov for any inquiries regarding NOAA Atlas 15.

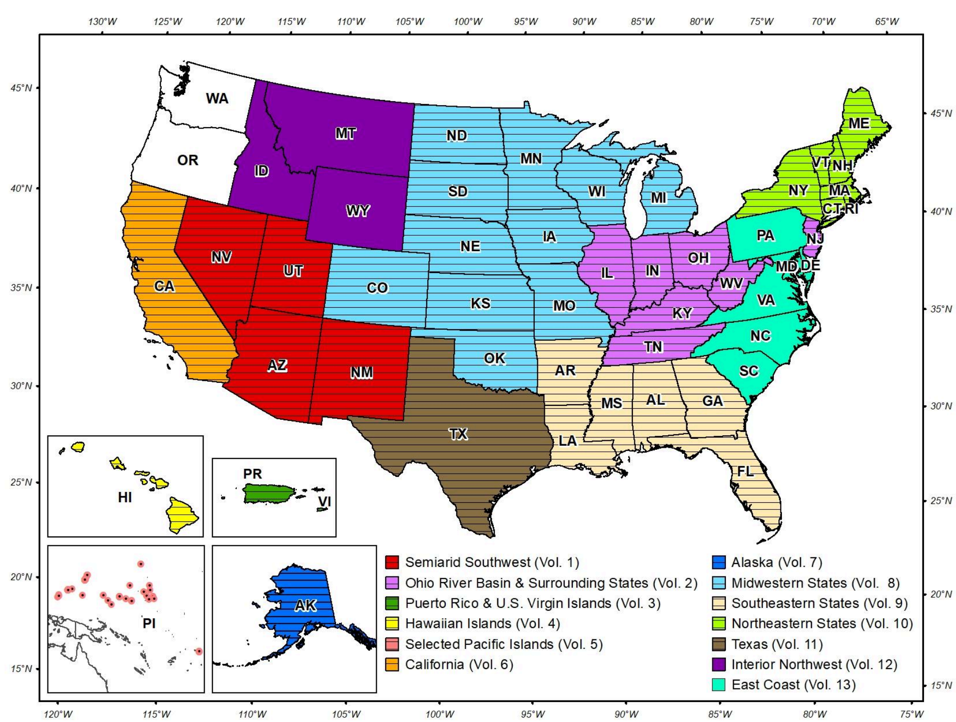

Figure 1. States or territories associated with each of the volumes of the Atlas.

II. CURRENT NOAA ATLAS 14 PROJECTS

1. VOLUME 12: INTERIOR NORTHWEST

On September 19, 2024, the HDSC published the NOAA Atlas 14 Volume 12 estimates for Idaho, Montana, and Wyoming. The development of this volume was initiated on May 26, 2021, and the project development area included the aforementioned states with an approximately 1-degree buffer around these states (Figure 2).

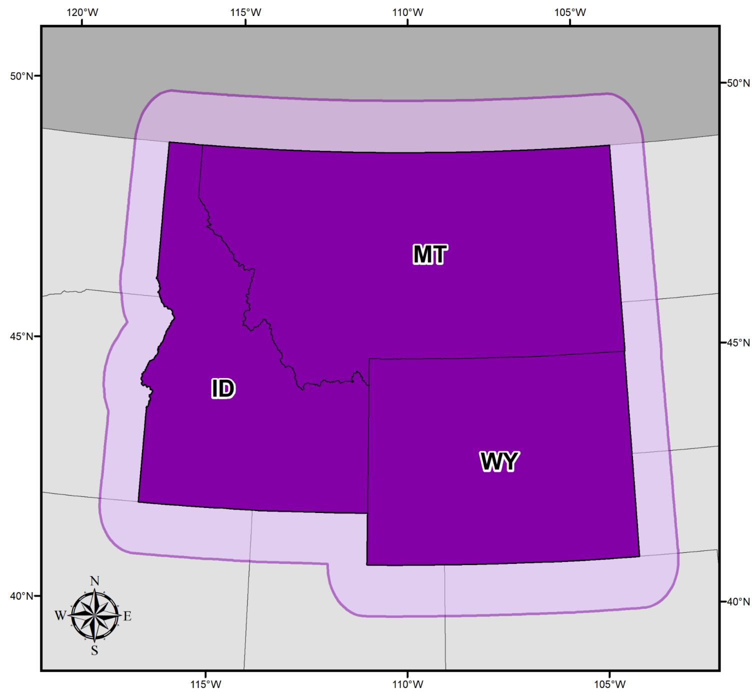

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of October 1 to December 31, 2024, we updated the Section 5 documentation, which covers the website functionality. This project is officially closed.

2. VOLUME 13: EAST COAST STATES UPDATE

OWP commenced the work on the NOAA Atlas 14 Volume 13 on July 28, 2022. 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.

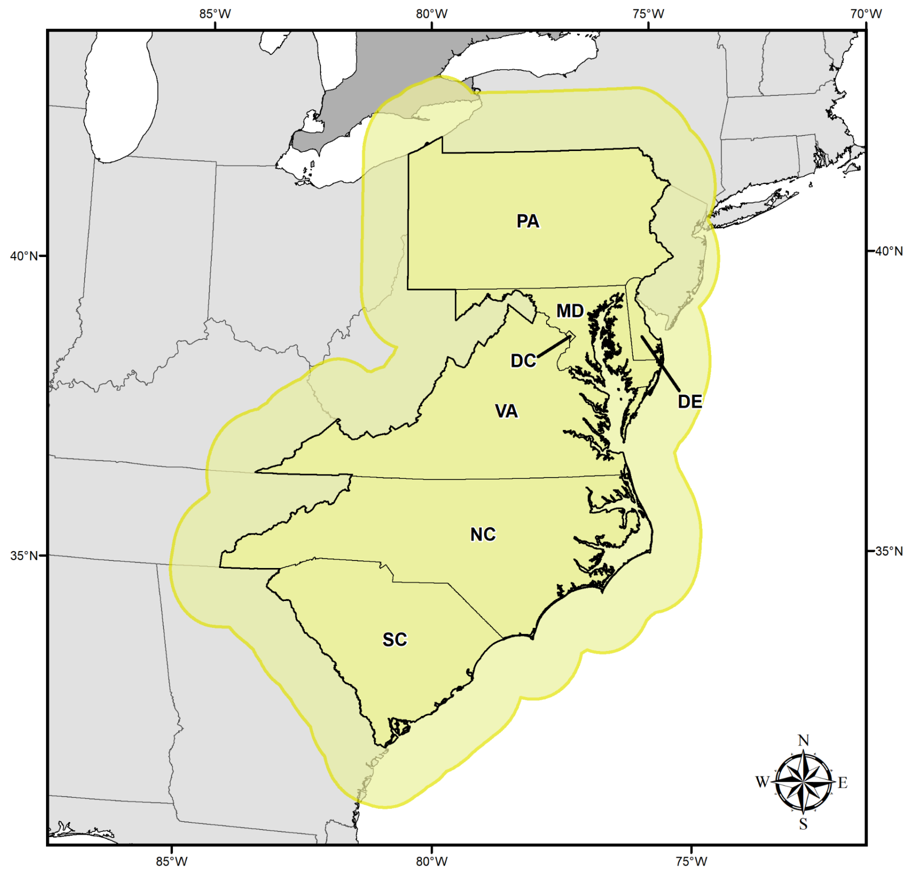

Figure 3. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (Sep - Dec 2024)

In the reporting period of Oct 1 to Dec 31, 2024, we completed the modernization of the station cleanup software and initiated the manual station cleanup for the co-located NCEI networks. Several datasets were extended through 2024. 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 screening

We continue to 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
20	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network	RAWS	Formatted
21	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network	SCAN	Formatted
22	U.S. Geological Survey (USGS) National Water Information System (NWIS)	Charlotte-Mecklenburg Hydrologic Network	CMHN	Investigating
23	University of Albany	New York State Mesonet	NYS	Formatted
24	University of Delaware, Center for Environmental Monitoring & Analysis	Delaware Environmental Observing System	DEOS	Formatted
25	University of Georgia	Georgia Weather Network	GWN	Formatted

FID	Data Provider	Dataset name	Abbr.	Status
26	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, USDA ARS, USGS NWIS (CHMN is being investigated) and WeatherSTEM.

2.1.2. Station metadata screening

In this reporting period, we continue to perform manual metadata inspection for datasets formatted (Table 2), and thus far completed the 95% of the metadata checks for all networks. See previous report on methodology here: January - March, 2024 QPR Report.

2.1.3. Station cleanup

The station cleanup effort is performed to:

- Screen for duplicate records
- Extend records at longer-duration stations using data from nearby stations,
- Investigate large differences in annual maximum series (AMS) at collocated stations at critical
- Durations such as 15-minute, 1-hour and 1-day
- Implement data corrections to ensure data consistency across multiple gauges
- Determining if overall datasets are of good quality and should be used in the analysis

In this reporting period, we implemented two rounds of automated merges:

- The automerge now runs 2 rounds of merges, the first with a 0.5 mile radius, the second with a 3.0 mile radius. In the second round merge, all deleted and stations incorporated into other stations via merges are excluded from grouping. In the second round merge, stations merged in the first round are reset so that the merges are in order of longest to shortest record.
- A check was implemented for stations' mean annual precipitation (MAP) from the Parameter-elevation Relationships on Independent Slopes Model (PRISM) during grouping of stations for possible merging. The MAP ratio (group min MAP/group max MAP) to determine when to split groups into 2 or more groups and/or prevent automatic merging of stations in the group (e.g. MAP values are too different for stations to be auto-merged).

See Table 3 for counts of stations originally, and then after merges/deletions. Note that a large number of stations are co-located in the "original" data, that is they are the same gauge, location, and/or from a different network/data source. After station cleanup, the number of stations is significantly lower. Figure 4 and 5 show location of the merged stations with 20 or more years of record within the project areas for hourly and daily durations, respectively.

Table 3: Counts of stations at each base duration.

	15-minute	1-hour	1-day
Original	1,123	3,480	16,401
Original >= 20 years	429	1,311	3,508
Merged >= 20 years	324	672	1,917

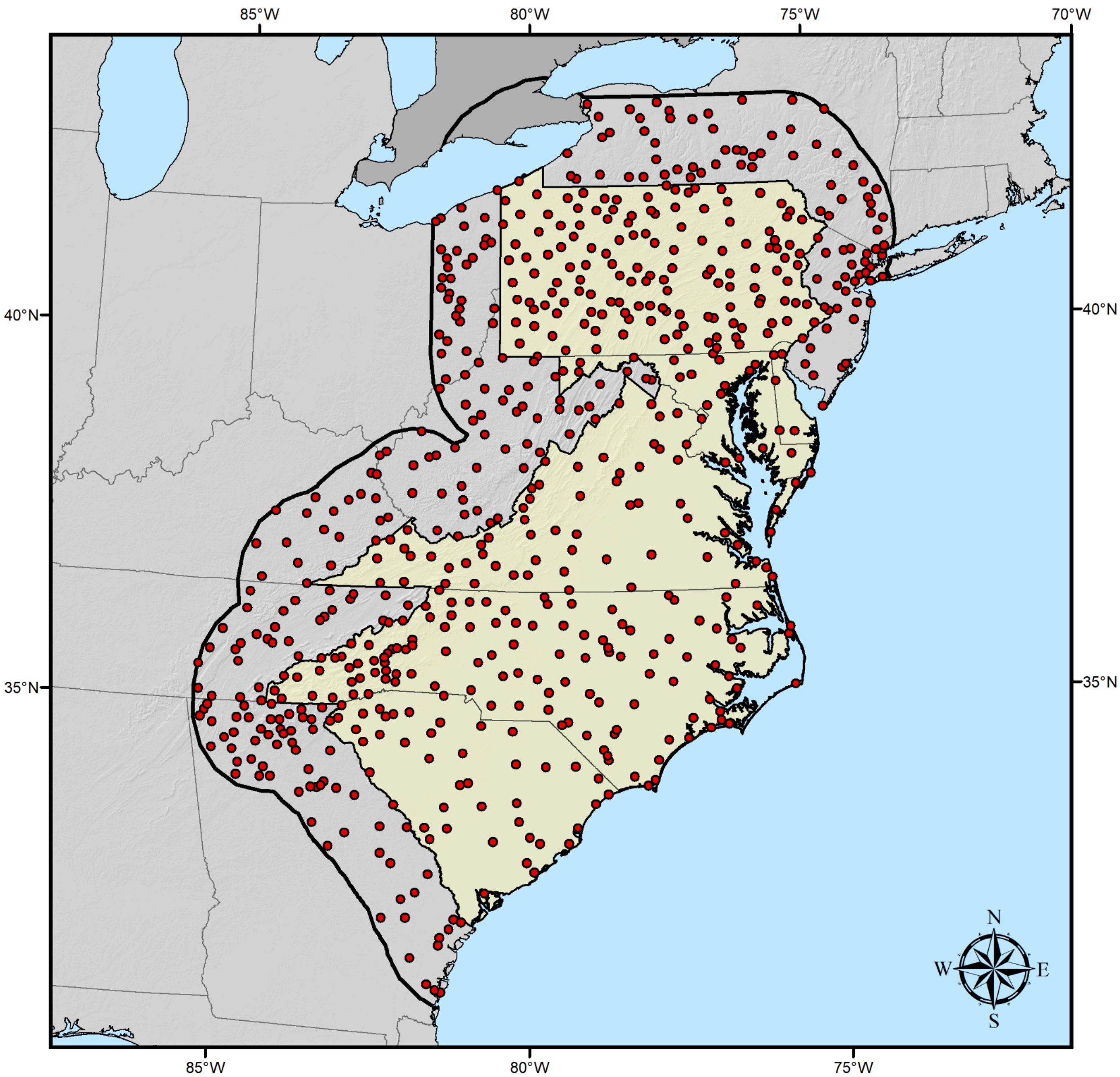

Figure 4. Merged stations at hourly durations with 20 or more years of record.

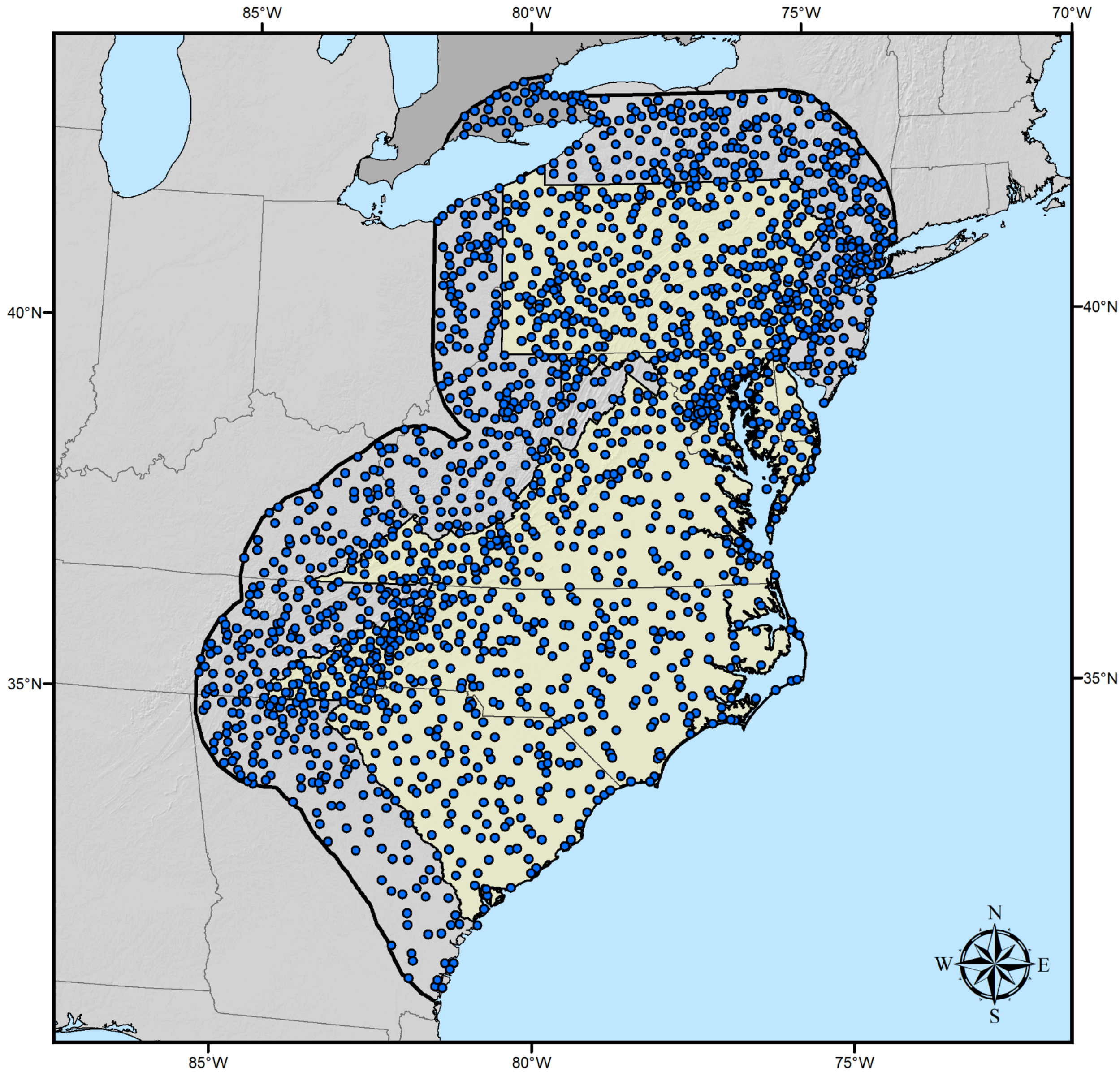

Figure 5. Merged stations at daily durations with 20 or more years of record.

2.1.4. Mean Annual Maxima (MAM) grids for base durations

We are exploring in-house development of mean annual maximum (MAM) precipitation grids for this project area. By comparing skill metrics such as mean squared error and R^2, we have identified the most critical covariates to include in stepwise multiple regressions to generate background MAM analyses. We have developed an ordinary kriging process to correct errors in that background correlated over large spatial scales (typically 100-200 km), and demonstrated, via leave-one-out cross validation, that the combination of stepwise multiple regression and ordinary kriging produces error metrics that are similar, and at times slightly improved, relative to the PRISM-based framework of previous Atlas 14 Volumes.

During this reporting period,, we generated initial versions of MAM grids for base durations (1 hour, 6 hours, 24 hours, and 10 days). We also investigated a third analysis (to follow the ordinary kriging step) which adjusts small-scale (50-100 km) residual errors in the analysis to better match station values, using radial basis function (RBF) interpolation**.** At this time, more work is needed to evaluate this step's performance and skill. We continue using cross-validation methods to optimize configurations and evaluate the results of our MAM analyses, and continue managing the code produced for this effort (mostly Python) on GitHub.

2.1.5 Extraction of the Rainy Season

During this reporting period, Python code was developed in order to extract the months when a majority of the Annual Maximum Series is occurring. We refer to this as the rainy season. The percent of AMS occurring in each month is calculated. Then a moving window is used to determine which span of months contain at least ⅔ of the total annual maximum series. In the event where there are multiple spans of months that contain ⅔ of the total AMS, the months that contain the larger percentage of AMS are considered the rainy season. If the tie cannot be broken based on AMS percentage, a wider range of months is used.

During the next reporting period, climate regions will be delineated based on spatial variations in the rainy season across the project area.

2.1.6 Extraction and quality control of annual maximum series outliers

The NCEP/EMC 4KM Gridded Data (GRIB) Stage IV Data was used to aid in discovery of “dry” hourly periods in the station precipitation data, in areas of sufficient radar coverage for approximately years 2005-present. This was tested on the COOP hourly dataset, in which 399 unflagged values >= 1.00”/hour were identified as likely invalid in the Volume 13 project area.

During this reporting period, no progress was made on this task. During the next reporting period, we will confirm the validity of these values, possibly identify more events through additional criteria, and expand the analysis to other sub-daily datasets.

2.1.7 Development of Precipitation Frequency Estimates

In NOAA Atlas 14, the MAM grids together with station regional precipitation frequency estimates are the basis for calculation of gridded precipitation frequency estimates and corresponding upper and lower bounds of the 90% confidence interval. For NOAA Atlas 14 Volume 13, precipitation frequency estimates are moving from L-moment statistics to a maximum likelihood approach. This method is a stationary analogue to the methods described in Section 4.3 of the Atlas 15 Pilot Technical Report. The stationary GEV probability distribution function applied to Atlas 14 is defined as:

$$f(x) \; = \; \frac{1}{\sigma(x)}\left\{1 \; - \; \xi(x)\frac{x-\mu(x)}{\sigma(x)}\right\}^{\left(\frac{1}{\xi(x)}-1\right)} \exp\left(- \; 1\left\{\xi(x)\frac{x-\mu(x)}{\sigma(x)}\right\}^{\frac{1}{\xi(x)}}\right)$$

where μ, σ, and ξ are location, scale, and shape parameters, respectively, and x is a spatial coordinate. For each region, the parameters are defined as:

Location: $\mu(x) \; = \; a_1 \times MAM(x)$

Scale: $\sigma(x) \; = \; b_1 \times MAM(x)$

Shape: $\xi(x) = c_0$

The location and scale parameters vary with a spatial covariate (MAM). Because of sensitivity to outliers, the shape coefficient is held constant to avoid generation of unreasonable values. Additionally, a lower bound is enforced on the scale parameter to ensure a non-negative result. The resulting parameters define a unique GEV distribution at each station's region.

During this reporting period, we developed initial gridded precipitation frequency estimates for durations between 1-hour and 10-days and for up to 100-year average recurrence intervals (ARIs).

2.1.8 Regionalization

The regionalization approach for the NOAA Atlas 14 Volume 13 also follows the regionalization approach described in NOAA Atlas 15 Pilot Documentation. The Atlas 15 regionalization approach to a great degree mimics the Atlas 14 approach, with the exception that the NOAA Atlas 14 Volume 13 methodology is fully automated and that regional stations are weighted based on similarity with the target station characteristics identified through various spatial variables.

The regionalization approach involves the following steps:

Station Selection & Similarity Assessment:

For each target station, regional stations within a 160-km radius were identified. Similarity between target and regional stations was evaluated using:

- Geospatial metrics; i.e., distance between stations, and distance to coast.
- Climate metrics; i.e., differences in Mean Annual Precipitation (MAP) and Mean Annual Maximum (MAM) for select durations.
- Elevation differences and terrain complexity; i.e, obstacle height and elevation range along the path between stations, to account for mountain ridgelines or barriers.
- Statistical tests; i.e.,Chi-squared and Kolmogorov-Smirnov) to compare precipitation distribution similarity.

Attribute Weighting Process:

For each attribute minimum and maximum allowable values were pre-defined.

Weight Calculation:

- If an attribute value for a regional station exceeded the maximum allowable value (or fell outside the defined range), its weight (W) was set to 0.
- If the attribute value was within the allowable range, W was calculated using a triweight kernel function. This function assigns a weight starting at 1 (for values at the minimum bound) and gradually decreases to 0 as the value approaches the maximum bound (see Table 4).

Final Weight:

- The final weight for each regional station was the product of all individual attribute weights.

- If any single attribute for a regional station exceeded its maximum allowable value (resulting in W = 0 for that attribute), the station's final weight became 0, and it contributed nothing to the target station's precipitation estimates.

Stations with weights near 1 (geographically close, similar attributes, minimal terrain barriers) contributed most to the target station's precipitation estimates. Stations with weights approaching 0 (distant, dissimilar attributes, or separated by complex terrain) contributed less or nothing.

Table 4: Attribute bounds for the weights

Attribute	**Description**	**Min Bound**	**Max Bound**
Search Radius	Geographic search area around the target station	70 km	160 km
dMAM	Percentage difference in Mean Annual Maximum precipitation	40%	75%
dMAP	Percentage difference in Mean Annual Precipitation	70%	105%
dElev	Difference in ground elevation	700 m	1200 m
elevR	Elevation range along the path	1200 m	1700 m
elevOH	Obstacle height	600 m	1100 m
log10p2ST	Statistical similarity (log-transformed p-value from Chi-squared/KS tests)	$\log_{10}(5)$	$\log_{10}(20)$
dDist2Coast	Relative difference in distance to coast	1	3

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2025)

We will finish data collection, reformatting, and quality control on data received for 2024, which includes data from Helene. In parallel, we will finish developing MAM grids for base durations for the development of the preliminary estimates over this domain. We will review maps of the resulting estimates for the 2-year and 100-year ARIs. Inconsistent estimates or unreasonable patterns are resolved on a case-by-case basis in various ways: by manually adjusting the value to reflect expected patterns, omitting the station from the analysis, or by adding anchoring estimates at critical ungauged locations.

2.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [FY Q1 2025; 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)] [FY Q2 2025; In Progress]
- Regionalization and frequency analysis [FY Q2 2025; In Progress]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [FY Q3 2025; In Progress]
- Peer review [FY Q3 2025; In Progress]
- Revision of PF estimates [FY Q3 2025]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [FY Q1 2026]
- Web publication [FY Q1 2026]

III. ATLAS 15: PRECIPITATION FREQUENCY STANDARD UPDATE

With funding support from the Bipartisan Infrastructure Law (BIL), NOAA is developing and implementing NOAA Atlas 15, the future authoritative source and national standard for precipitation frequency information. When published, NOAA Atlas 15 will have nationwide coverage and account for temporal trends, and represents a shift from a stationary assumption (i.e. extreme precipitation patterns do not change over time) to a nonstationary assumption.

NOAA Atlas 15 will contain two volumes and will supersede NOAA Atlas 14 when published in 2026 and 2027. Volume 1 will use the latest observed precipitation data and nonstationary statistical methods to generate spatially continuous precipitation frequency estimates that represent the most current conditions. Volume 2 will leverage climate model outputs to project Volume 1 estimates into future time periods as part of two distinct frameworks: global warming level (GWL) and emission scenario.

In order to collect feedback early in the development process on the structure of the Atlas 15 Pilot data and web dissemination strategy, OWP released the NOAA Atlas 15 Pilot data over the state of Montana on September 26, 2024. The data and web dissemination strategy will be revised before the final studies are published in 2026 and 2027 for the CONUS and oCONUS, respectively. For more information on the NOAA Atlas 15 development, please visit the NOAA Atlas 15 Informational Page or email us at atlas15.info@noaa.gov for any inquiries regarding NOAA Atlas 15.

In this reporting period, we completed significant outreach with stakeholders to share the outcome of the Pilot project over Montana and encourage feedback. Feedback on the NOAA Atlas 15 Pilot can be provided through March 6, 2025. For more information on the Atlas 15 Pilot release, please refer to the July - Sept, 2024 Progress Report.

In parallel, during this reporting period, the Atlas 15 technical team initiated expansion of the Pilot framework over CONUS, and continues to collect, format and quality control observed extreme time series data and continues to format, evaluate, and process CONUS climate model outputs for various durations. The next Atlas 15 development milestone will be the publication of the CONUS preliminary estimates in 2025.

NOTE: The release of Atlas 15 pilot data is intended for comparison and feedback purposes as it has not completed the peer review process. The Atlas 14 Volume 12 data released on September 19, 2024, is the authoritative source and standard for Montana.

IV. WORKSHOPS AND CONFERENCES

During this reporting period, we completed significant outreach with stakeholders to share the outcomes of the NOAA Atlas 15 Pilot Project over the state of Montana and encouraged feedback. The majority of the presentations were delivered virtually, with the exception of Dr. Janel Hanrahan's presentation on the Atlas 15 Pilot development at the American Geophysical Union (AGU) Annual Meeting on December 9, 2024, in Washington, D.C.