Hydrometeorological Design Studies Center
Progress Report for Period
1 July to 30 September 2023

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.

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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.

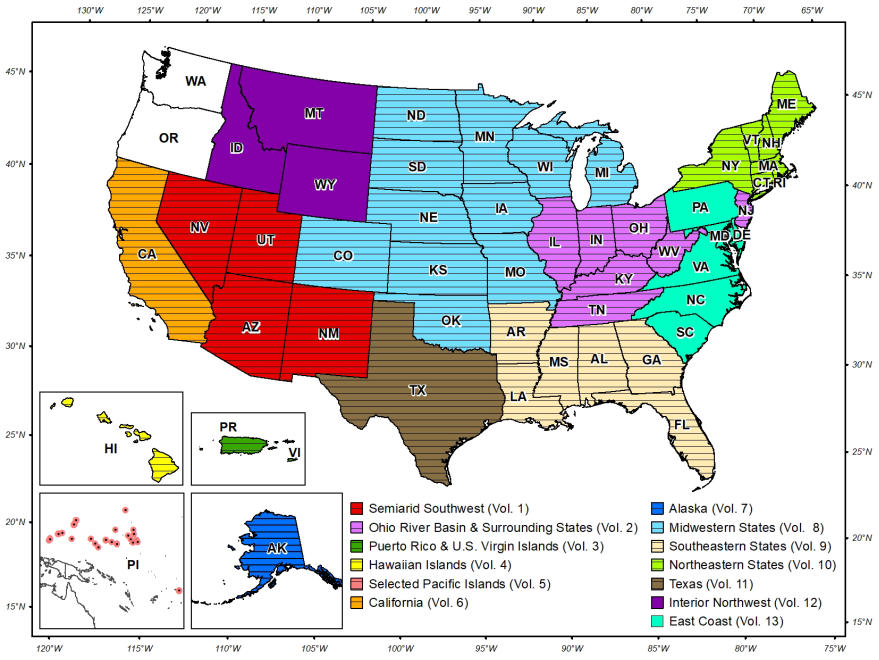


Figure 1. States or territories associated with each of the volumes of the Atlas.

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 Q2 of 2024.

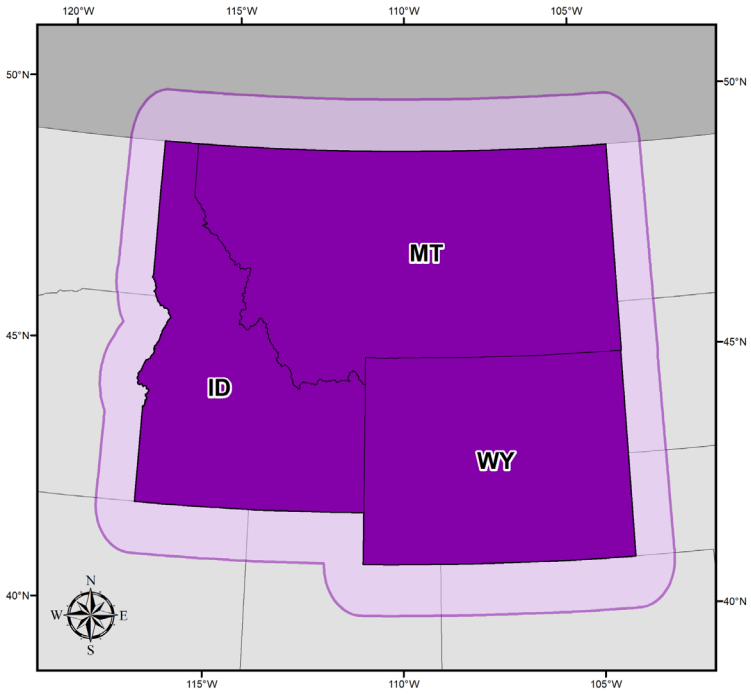


Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of July 1 to Sep 30, 2023, we finalized the preliminary estimates for durations ranging from 1 hour to 10 days and average recurrence intervals spanning from 2 to 100 years. To complete the preliminary estimates for the selected durations and average recurrence intervals, all the gauge locations were regionalized, and additional rounds of mean annual maximum and quality control tasks were completed. For the information on how regionalization, mean annual maximum and quality control tasks are performed, please refer to July - Sept, 2022 Progress Report. In addition, we finalized the analysis of at-station DDF curves and the development of the Peer Review webpage.

1.1. PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2023)

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. Analysis of PF estimates (2-year/100-year) spatial patterns and at-station DDF curves

In NOAA Atlas 14, the interpolated MAM grids together with at-station 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 a selected duration, development of precipitation frequency grids utilizes the inherently strong (zero-intercept) linear relationship that exists between consecutive precipitation frequency estimates, as well as between 2-year precipitation frequency estimates and MAM.

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

1.1.2. Peer review

All NOAA Atlas 14 Volumes are subject to peer review which provides critical feedback on the reasonableness of point precipitation frequency estimates, their spatial patterns, and station metadata. This allows us to incorporate the reviewers' local knowledge of rainfall patterns and rain gauge networks into the final product.

On October 12, 2023 we published the preliminary (Version 1) results for Volume 12 on the peer review page (see Figure 3) and sent an invitation for the review to individuals who expressed interest in the review and/or subscribed to our list server. The peer review process will conclude on November 30, 2023. At that time, we will consolidate all comments, review and address them accordingly. We will publish all comments (anonymously) with our resulting action as Appendix 4 of Volume 12 document.

The preliminary results published on the peer review pages should not be used in design since they are subject to change. The final estimates with supplementary information will be delivered via the Precipitation Frequency Data Server, and will be similar in format to previous volumes. We expect to publish the final estimates by the end of Q2 of 2024 as NOAA Atlas 14 Volume 12 Version 2.

For the review we have provided the following Volume 12 preliminary products and encouraged peer reviewers to make comments on:

a. Station metadata. A total of 15,305 stations from 34 datasets were grouped into three categories: a) stations inside the Interior Northwest that were used in frequency analysis (shown as green squares on the map in Figure 3), b) stations outside the Interior Northwest that assisted in the analysis (yellow squares), and c) stations that were examined but not retained for the analysis (red squares). We asked reviewers to examine the accuracy of stations' coordinates and provide comments on suggested stations' deletions, merges and co-locations.

b. At-station depth-duration-frequency (DDF) curves. We provided DDF curves for stations retained in analysis for durations between 1-hour and 10-days for average recurrence intervals from 2-year through 100-year. We asked reviewers to examine the curves and let us know if precipitation frequency estimates at the station are in line with expected values.

c. Spatially-interpolated estimates. We created cartographic maps of spatially-interpolated precipitation frequency estimates for 2-year and 100-year ARIs and for 60-minute, 6-hour, 24-hour and 10-day durations (8 maps total) and invited reviewers to comment on the overall and local spatial patterns. Figure 4 shows, as an example, a cartographic map of 100-year 24-hour

estimates. For more information on NOAA Atlas 14 frequency analysis and interpolation methods, see, for example, the NOAA Atlas 14 Vol 11 document.

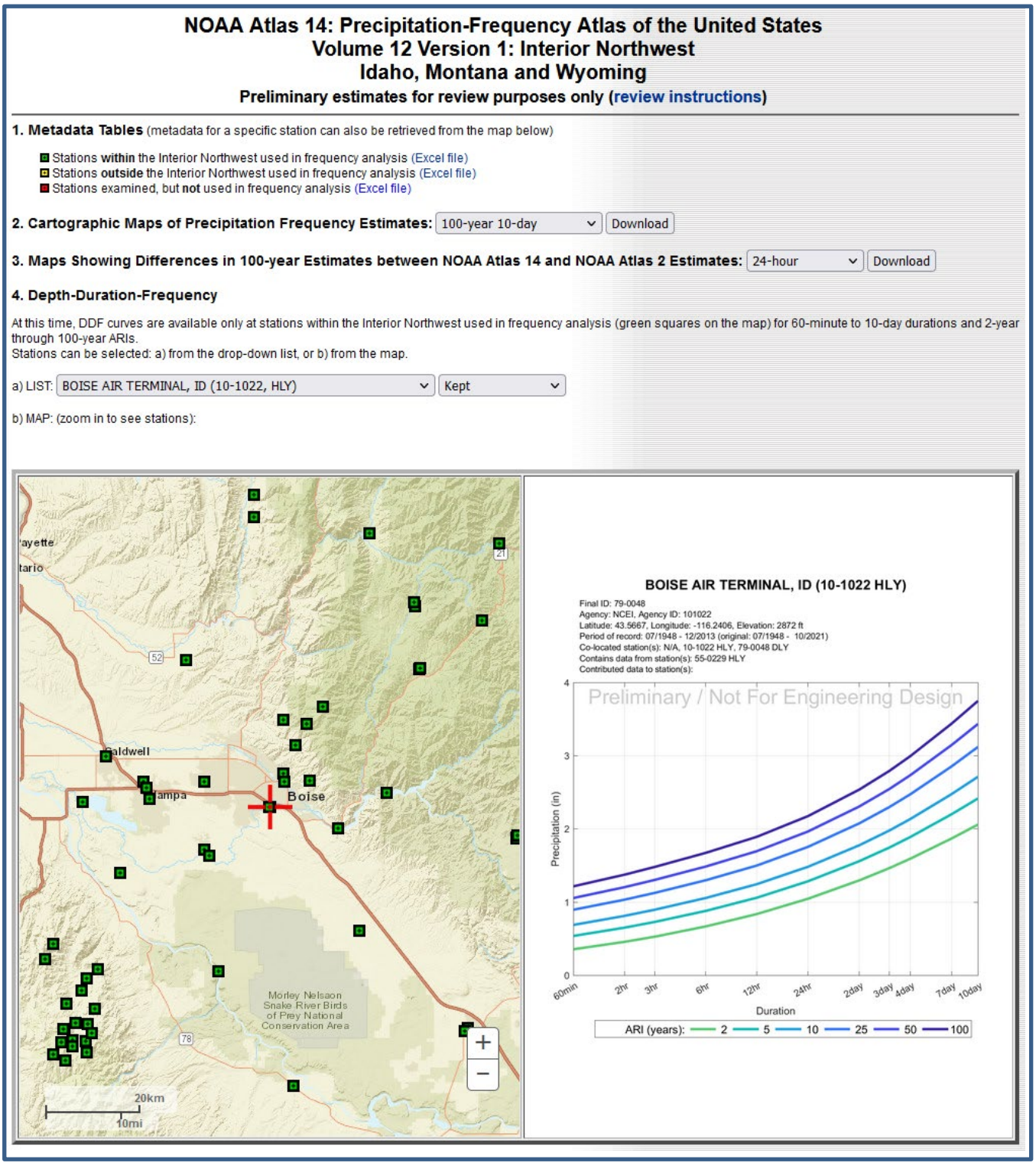


Figure 3. Peer review page for Volume 12.

To illustrate how much estimates changed in the project area, we also created cartographic maps for 100-year estimates showing differences between NOAA Atlas 14 and currently valid NOAA Atlas 2 estimates for 6-hour and 24-hour durations. For this comparison, we used digitized grids based on spatial interpolation of relevant NOAA Atlas 2 cartographic maps. The map in Figure 5 shows the differences in 100-year 24-hour estimates (in inches) between NOAA Atlas 14 and NOAA Atlas 2. The differences in estimates between the two publications are attributed to a number of factors, including differences in frequency analysis, spatial interpolation techniques and in the amount of available data, both in the number of stations and their record lengths, etc.

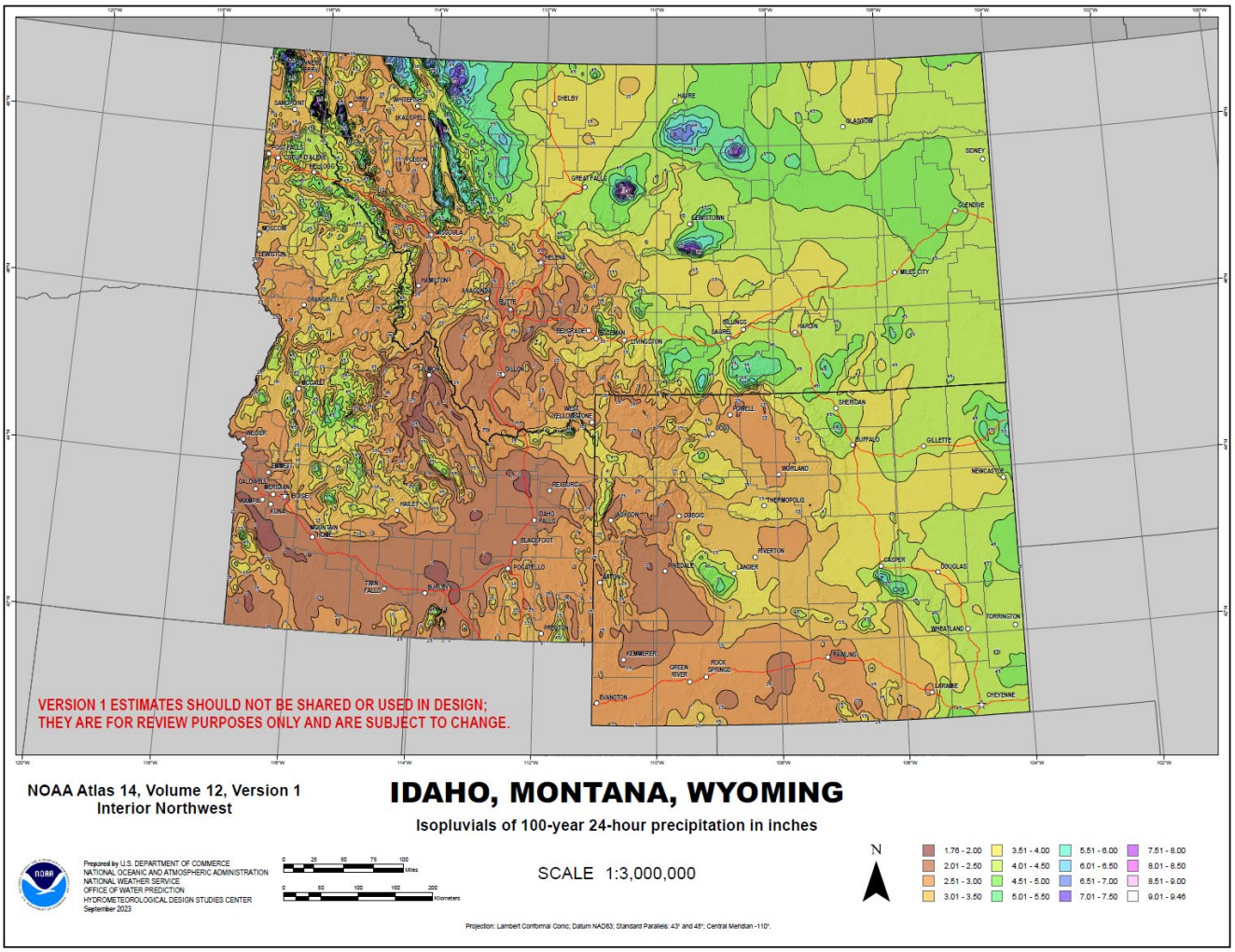


Figure 4. Cartographic map showing 100-year 24-hour estimates (in inches) from NOAA ATLAS 14 Vol 12 Version 1.

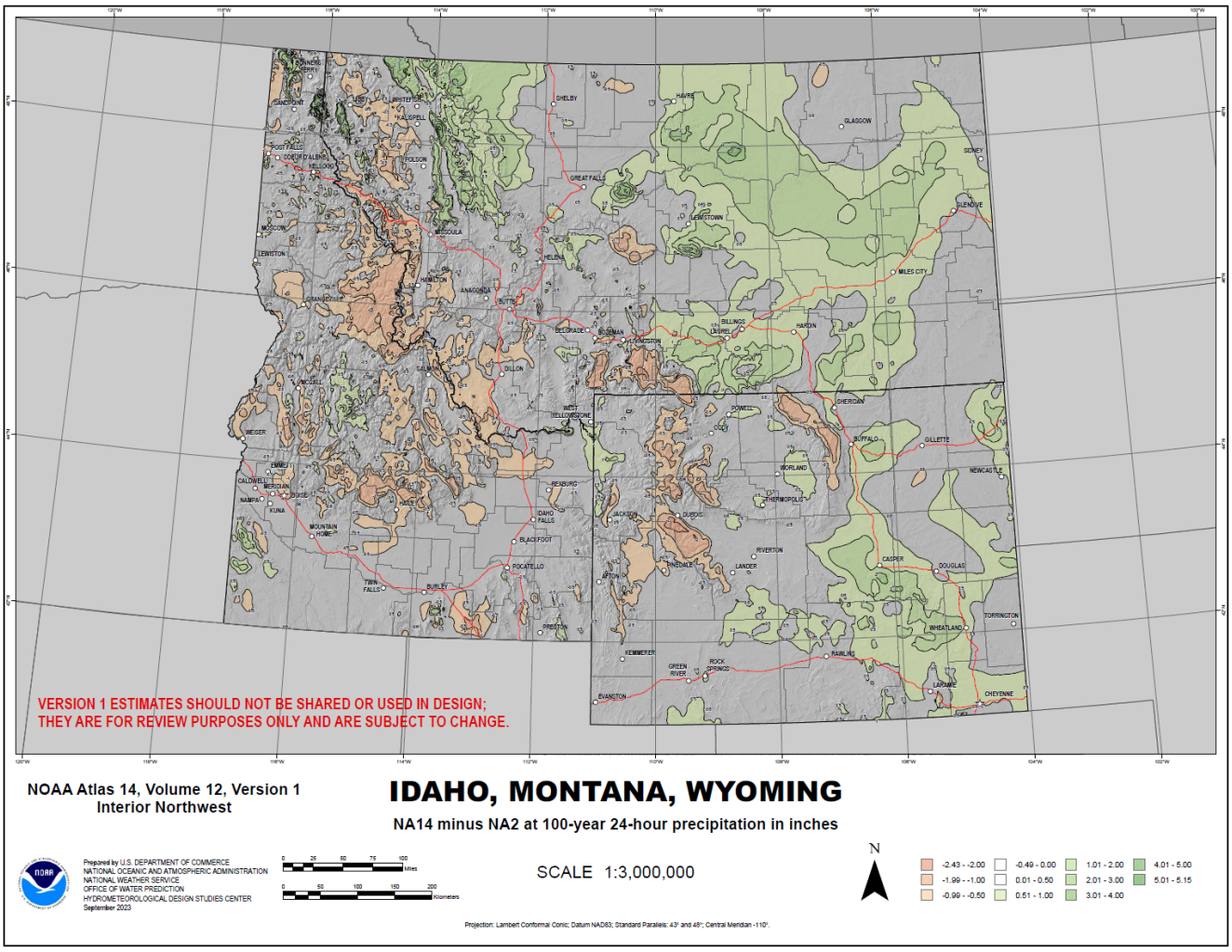


Figure 5. Map showing differences in 100-year 24-hour estimates (in inches) between NOAA ATLAS 14 Vol 12 Version 1 and NOAA Atlas 2.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2023)

In the next reporting period, we will update datasets for the most recent precipitation record where available and extract AMS for years appended. We will consolidate, review and address comments received from reviewers and work on trend, and rainfall precipitation frequency analysis

The project milestone schedule has been revised to align with the availability of funds and personnel (current and projected).

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 [Q4 2023]
- Revision of PF estimates [Q2 2024]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [Q2 2024]
- Web publication [Q2 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 5). 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. During this reporting period, OWP established a NOAA Atlas 14 focused grant through the NOAA Cooperative Institute for Research to Operations in Hydrology (CIROH) to comprehensively support research and development activities across multiple Atlas 14 volumes.

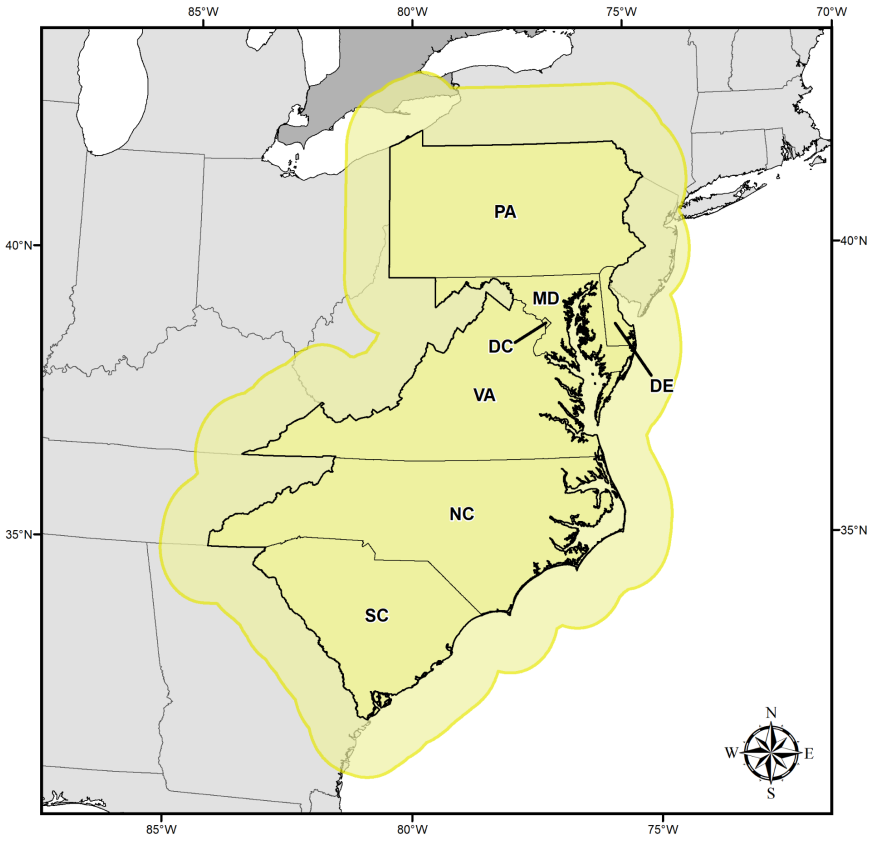


Figure 6. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (July - Sep 2023)

2.1.1. Data collection and data screening

During the July 1 to Sep 30, 2023 reporting period, we completed compiling a list of precipitation networks that will be 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	GHCN-DAILY	Formatted
4		Environment Canada	GHCN-DAILY	Formatted
5		Integrated Surface Data (Lite)	ISD_LITE	Formatted
6		Local Climatological Data	LCD	Formatted
7		Hourly Precipitation Data (HPD) v1.0 Beta and v2.0 Beta	HPDv1, HPDv2	Formatted
8		United States CoCORAHS	GHCN-DAILY	Formatted
9		Canada CoCORAHS	GHCN-DAILY	Formatted
10		Weather Bureau Army Navy (WBAN)	GHCN-DAILY	Formatted
11		U.S. Climate Reference Network	USCRN	Formatted
12	Aberdeen Proving Ground	Phillips Airfield Weather Station	PAWS	Received
13	Hampton Roads Sanitation District		HRSD	Received
14	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	Received

FID	Data Provider	Dataset name	Abbr.	Status
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	Received
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. Department of Agriculture (USDA)	Agriculture Research Service	ARS	Received
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
23	U.S. Geological Survey (USGS)	National Water Information System	NWIS	Investigating
24	University of Albany	New York State Mesonet	NYS	Received
25	University of Delaware, Center for Environmental Monitoring & Analysis	Delaware Environmental Observing System	DEOS	Formatted
26	University of Georgia	Georgia Weather Network	GWN	Formatted
27	Western Kentucky University	Kentucky Mesonet	KYM	Received

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.

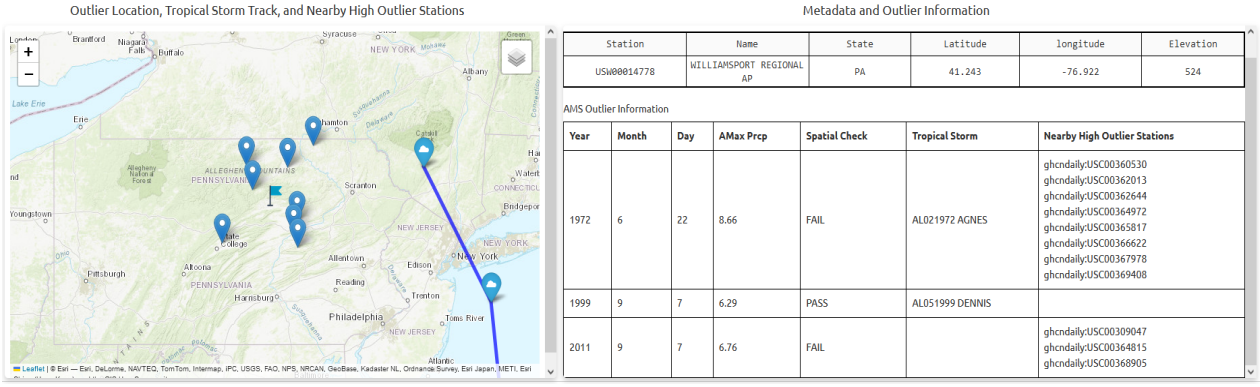
2.1.2. Station metadata screening

Python-based software has been developed to modernize and automate our station metadata quality control system. To ensure accuracy in NCEI datasets, any discrepancies in the elevation, latitude, and longitude of individual stations are first rectified using the latest station metadata entry from the NCEI's Enhanced Master Station History Report (EMSHR). Furthermore (and for all other datasets), station location is marked for additional review by conducting two tests: elevation differences over 150m and locations outside of the 1-minute precision box. In the first test, DEM was derived for all stations, and then the extracted DEM was compared to the station metadata elevation to determine whether the station elevation was accurate. Next, a 150 m absolute difference threshold is applied to select all stations with an elevation difference relative to the DEM that exceeds 150 m. The minimum and maximum elevations from the DEM are extracted after constructing a one-minute square box around the center of all the stations from the preceding test. The station elevations that do not fall within the minimum and maximum DEM elevations are flagged for manual review. These tests are especially beneficial for stations whose precision is off by a few seconds, which can result in a location error of over a mile. In this reporting period, 151 NCEI stations that could not be adjusted automatically based on the current data format were manually inspected, and 135 stations were manually adjusted. The team continues to perform manual inspection for other datasets formatted (Table 2).

2.1.3. AMS QC Visualization Dashboard

A Python-based dashboard has been developed to aid in the quality control of high-outlier precipitation events, with the goal of establishing a one-stop shop graphical user interface for all necessary information to manually quality control high-outlier precipitation events. The QC visualization dashboard features include:

- The map on the left illustrates the location of the reference outlier station, the tropical storm track, and surrounding high-outlier stations (left side of Figure 7).
- Table with metadata information such as outlier station's name, location, and elevation, as well as its high-outlier event times and annual maximum values. Furthermore, the table contains information if the high-outlier passed or failed the spatial check with neighboring stations (right side of Figure 7).
- Displays the local storm report for the event without the need to manually access the storm event database outside of the dashboard. The dashboard automatically scrapes the cooperative observer form (COOP), local climatological data, hourly precipitation data, and storm data from the NCEI image publication system. These forms are necessary to confirm or dispute the high outlier event (confirm weather event or an erroneous value).
- Intensity-Duration-Frequency (IDF) curve for the reference stations (left side of Figure 8).
- Spatial map of maximum precipitation at the reference outlier station and neighboring stations, including a stage IV radar precipitation overlaid on the spatial map to corroborate the at-station gauge precipitation (right side of Figure 8).

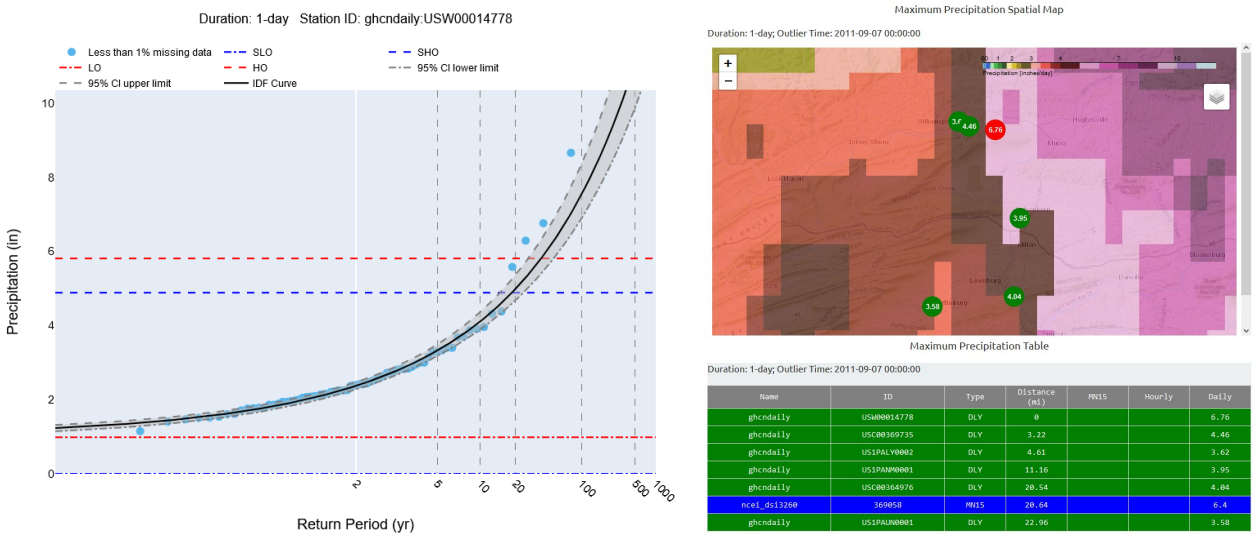


Station	Name	State	Latitude	longitude	Elevation
USW00014778	WILLIAMSPORT REGIONAL AP	PA	41.243	-76.922	524

AMS Outlier Information

Year	Month	Day	AMax Prcp	Spatial Check	Tropical Storm	Nearby High Outlier Stations
1972	6	22	8.66	FAIL	AL021972 AGNES	ghcndaily:USC00360530 ghcndaily:USC00362013 ghcndaily:USC00362644 ghcndaily:USC00364972 ghcndaily:USC00365817 ghcndaily:USC00366622 ghcndaily:USC00367978 ghcndaily:USC00369408
1999	9	7	6.29	PASS	AL051999 DENNIS	
2011	9	7	6.76	FAIL		ghcndaily:USC00309047 ghcndaily:USC00364815 ghcndaily:USC00368905

Figure 7. Left: Map displaying outlier station location, tropical storm track, and nearby high-outlier stations. Right: outlier station metadata and high-outlier events.



Name	ID	Type	Distance (mi)	MN15	Hourly	Daily
ghcndaily	USW00014778	DLY	0			6.76
ghcndaily	USC00369735	DLY	3.22			4.46
ghcndaily	US1PALY0002	DLY	4.61			3.62
ghcndaily	US1PANM0001	DLY	11.16			3.95
ghcndaily	USC00364976	DLY	20.54			4.04
ncei_ds13260	369058	MN15	20.64			6.4
ghcndaily	US1PALN0001	DLY	22.96			3.58

Figure 8. IDF curve (left) and spatial map (right) of maximum precipitation at outlier and neighboring stations.

2.1.4. Investigating spatial covariates

During this reporting period, our focus remains on exploring spatial covariates within this project area. We are interested in identifying and incorporating spatial-varying covariates into the parameterization process, allowing parameters to vary in space at each grid point. For example, the spatial covariate, PRISM mean annual precipitation (MAP), is incorporated into the parameter optimization process, which allows for grid points to account for the effects of terrain.

We have identified several different spatial covariates, including slope, latitude, effective terrain height, coastal proximity, PRISM MAP, elevation, etc. Using multiple regression, we are attempting to determine the most critical covariates in this project area based on mean squared error and R^2. Our initial analysis has shown the potential to achieve favorable results in this project area. Consequently, we are continuing our investigation in this direction.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2023)

We will continue with data collection, reformatting, and station metadata checks for NCEI stations. All collected data will be examined and formatted into a common format, where appropriate. In parallel, we will continue to

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]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [Q3 2024]
- Peer review [Q4 2024]
- Revision of PF estimates [Q3 2025]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [Q4 2025]
- Web publication [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. Moreover, NOAA Atlas 15 will leverage the most recently available precipitation observations, and will provide enhanced supplemental products that will enable the design of robust and resilient climate ready civil infrastructure based on a rigorous process vetted through significant stakeholders interactions. NOAA Atlas 15 will be presented in two volumes to account for a changing climate. Volume 1 will account for temporal trends in historical observations, and Volume 2 will use future climate model projections to generate adjustment factors that can be used with Volume 1 estimates to project future conditions.

NOAA has established contract vehicles and grants to support this effort as well as a detailed project schedule with key milestones for the duration of the entire project which is expected to last 4 years. Preliminary estimates over the contiguous U.S. will be released in 2025 ahead of the peer-reviewed publication in 2026. With contracts and grants in place, a technical kickoff meeting was held on July 10, 2023 to bring together the dedicated teams that will be working towards achieving project milestones.

In this reporting period, the Atlas 15 team initiated the 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

IV. OTHER

1. CONFERENCES

The HDSC team has been keeping various stakeholders updated on the progress of the Atlas 15 project. In this reporting period, Sandra Pavlovic provided a status update to the EPA's National Pollutant Discharge Elimination System (NPDES) Climate Change meeting on Monday, September 11, 2024, and USACE Annual 2023 Hydrologic Engineering Committee on Tuesday, September 12, 2023, on the development of precipitation frequency estimates.