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

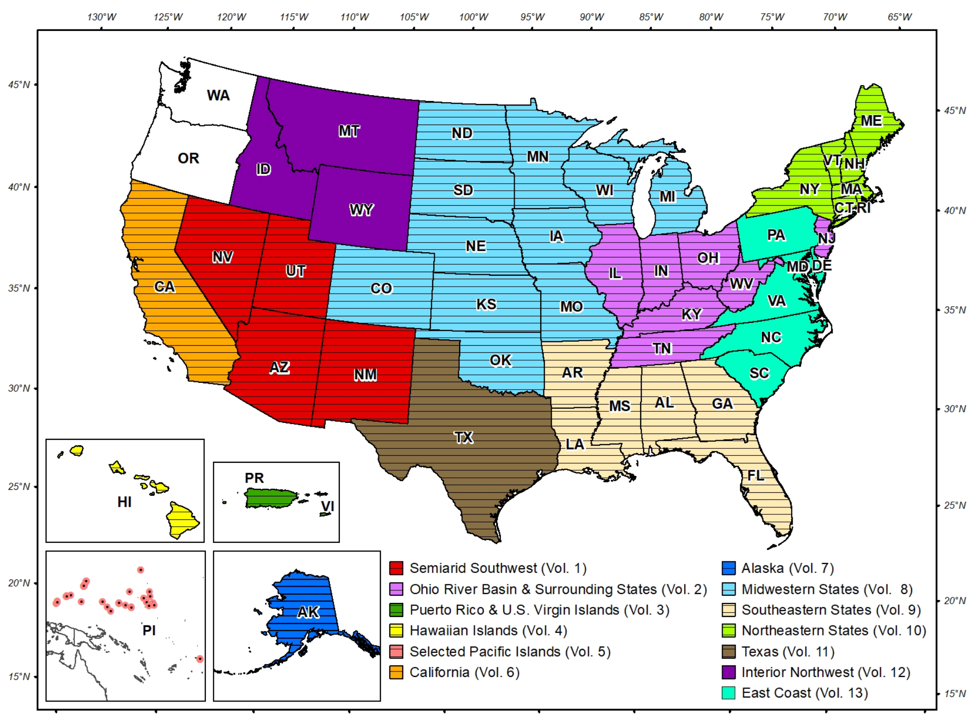

Figure 1. States or territories associated with each of the volumes of the Atlas.

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.

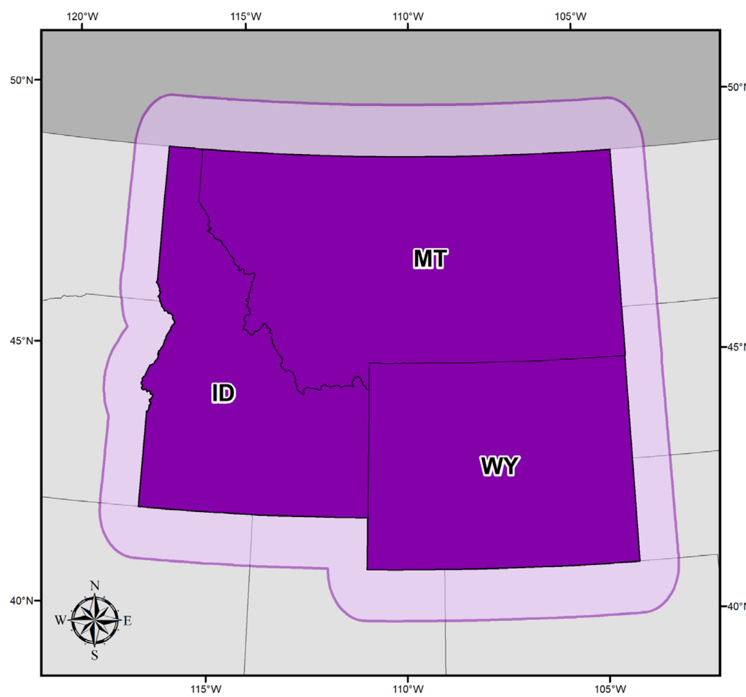

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

In the reporting period of October 1 to December 31, 2023, we completed and shared the preliminary estimates for review with individuals who expressed interest in the review and/or subscribed to our list server. The Peer Review commenced on October 12 and completed on December 22, 2023. In this period, we also compiled the received feedback and started to address it. In addition, in this reporting period, we completed an additional round of station cleanup for all stations in the analysis using a 4-mile radius. We updated the high priority daily datasets, such as NCEI's Global Historical Climatology Network daily (GHCNd) and USDA's automated Snow Telemetry (SNOTEL) network, through the end of October 2023, and we also started our final quality control task of all daily data on the annual maximum series data 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 (Oct - Dec 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. 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 concluded on Friday, December 22, 2023. At that time, we consolidated and reviewed all comments, and started to address them accordingly.

We received 10 responses from federal, state agencies and the private sector. Concerns raised were regarding inconsistencies between durations, abrupt/abnormal increases/decreases relative to Atlas 2 and differences in some locations when compared to previous NWS and private sector studies. HDSC began reviewing these comments and will address them accordingly.

We will publish all comments (anonymously) with our resulting action as Appendix of Volume 12 document. We greatly appreciate everyone who participated in the Peer Review to help improve the final precipitation frequency estimates for this project area.

For the review, we 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.

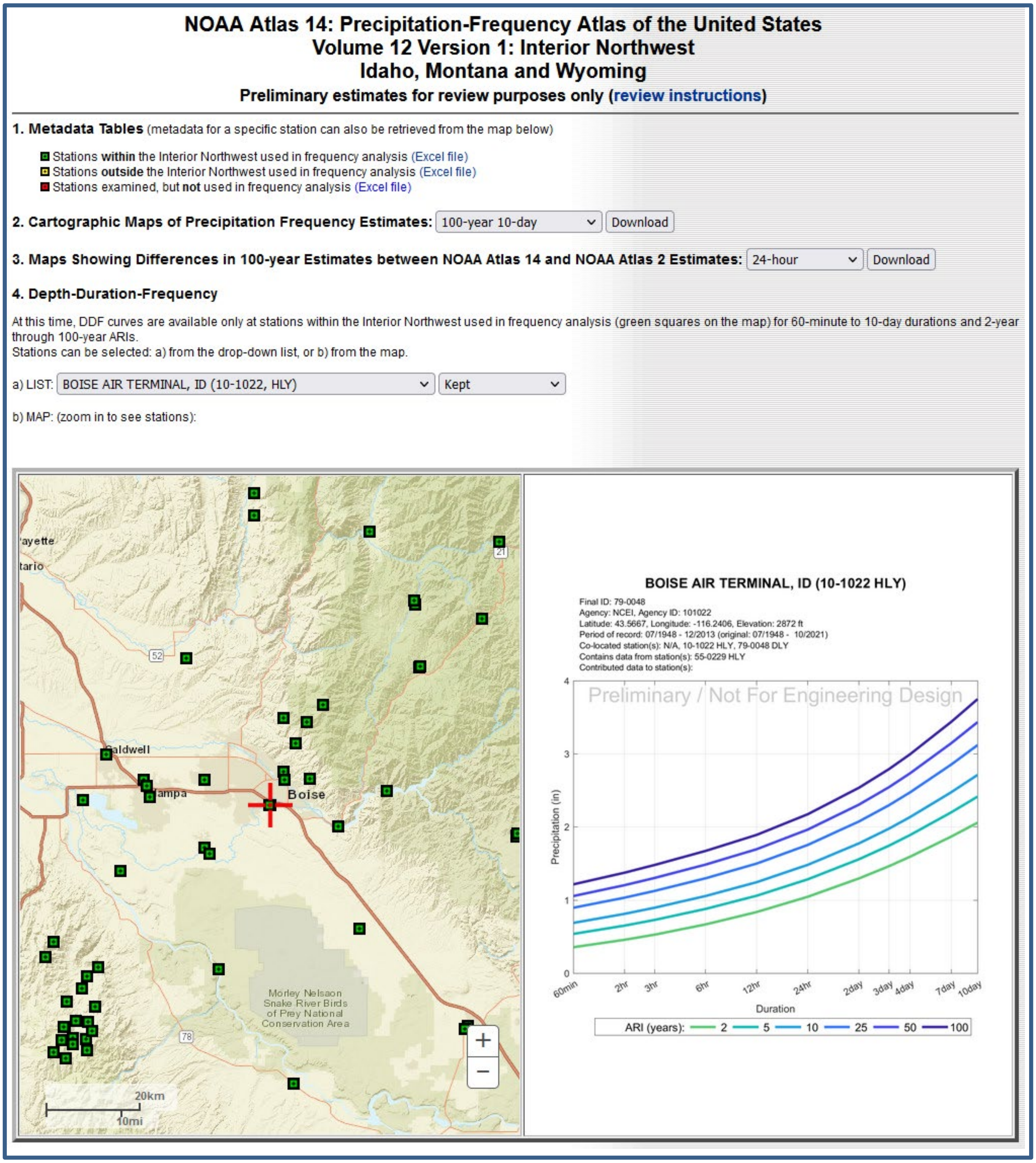

Figure 3. Peer review page for Volume 12.

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.

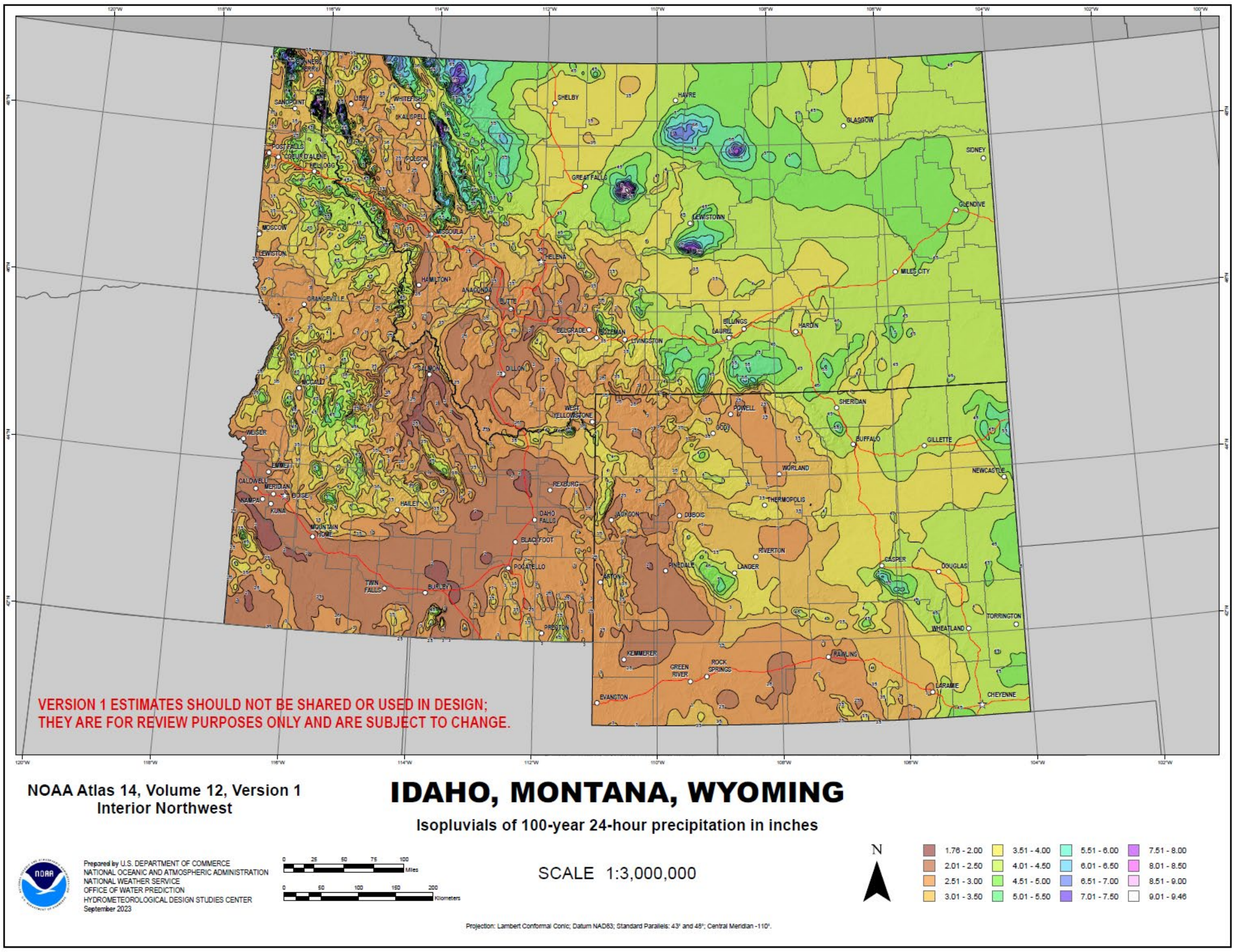

Figure 4. Cartographic map showing 100-year 24-hour estimates (in inches) from NOAA ATLAS 14 Vol 12 Version 1.

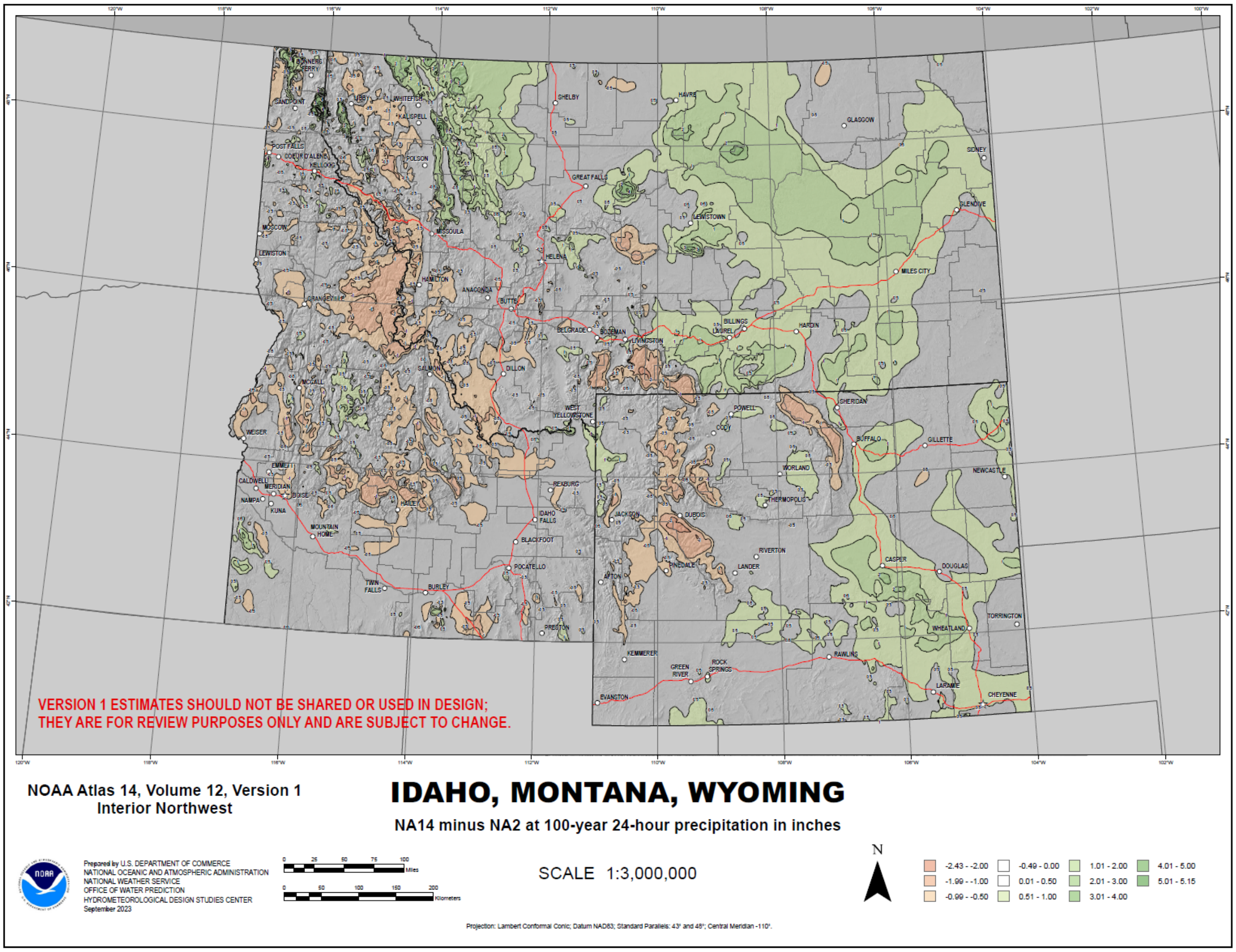

Figure 5. Map showing differences in 100-year 24-hour estimates (in inches) between NOAA ATLAS 14 Vol 12 Version 1 and NOAA Atlas 2.

1.1.2. 4-mile Cleanup

In this reporting period, we completed and implemented changes from another round of cleanup, which looked at all stations within a 4-mile radius. 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 within a target radius. 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. After reviewing 1,146 cases we implemented 101 data merges and/or extensions, 29 deletes, and 103 data corrections.

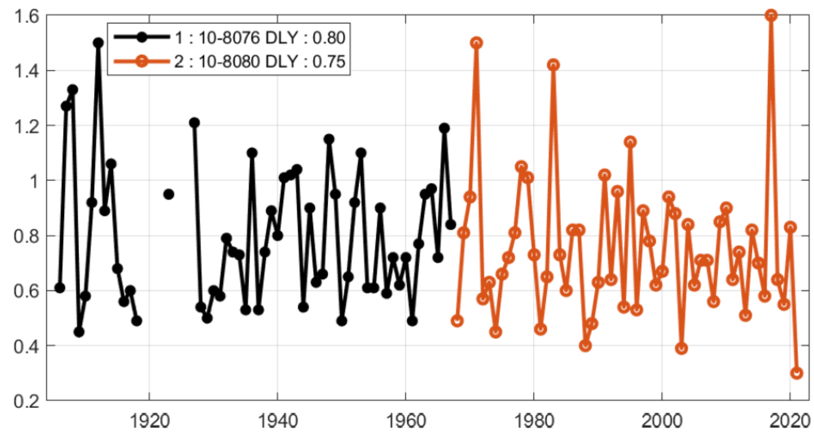

Fig 6. Example of merged daily stations Salmon AP and Salmon-KSRA that are 2.07 miles apart.

1.1.3. 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 worked on the final quality control task for daily durations 1-day through 60-day. There are a total of 3,752 high outlier values across all daily durations for all stations, and this includes events in the analysis from 2022 and 2023 after we appended data for these two years for NCEI's Global Historical Climatology Network daily (GHCNd) and USDA's automated Snow Telemetry (SNOTEL) networks.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2024)

In the next reporting period, we will continue to update datasets with the most recent precipitation record where available and extract AMS for the appended years. We will address comments received from reviewers and work on developing the final precipitation frequency estimates, and supplemental information (e.g. rainfall analysis, seasonality, temporal distributions, and documentation).

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 [In Q2 2024; In Progress]
- 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 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.

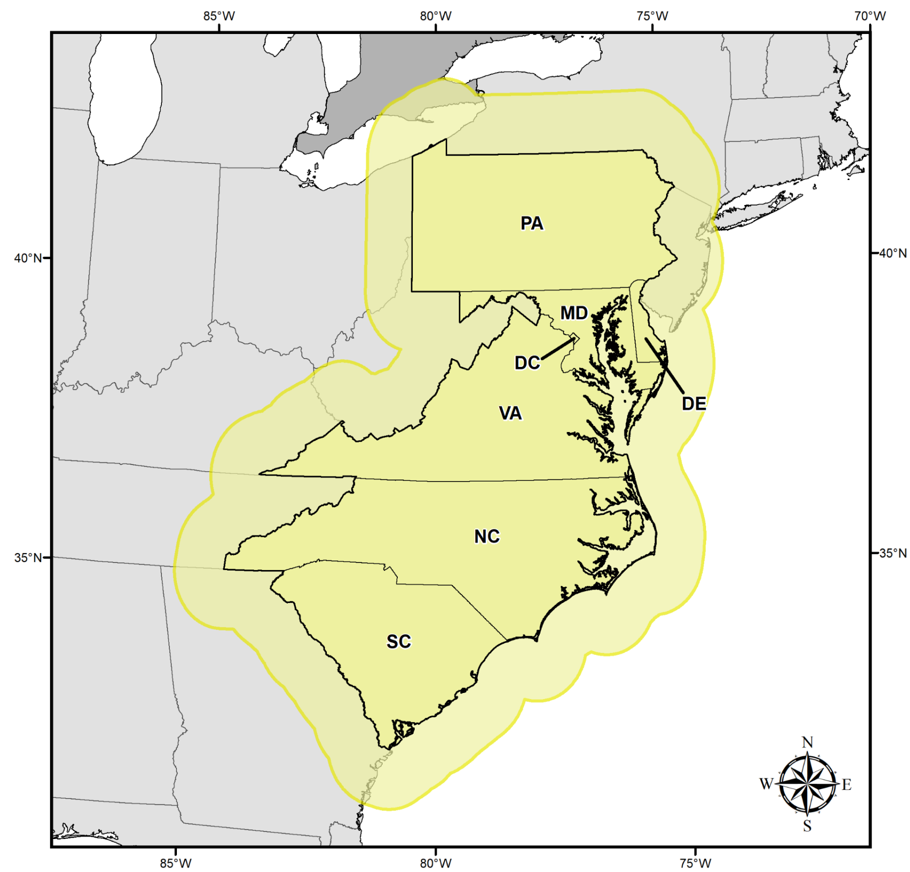

Figure 7. NOAA Atlas 14, Volume 13 extended project area (shown in yellow).

2.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2023)

2.1.1. Data collection and data screening

During the Oct 1 to Dec 31, 2023 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	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
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	Investigating
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	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. Annual maximum series (AMS) extraction

The precipitation frequency analysis approach we used in this project is based on AMS analysis across a range of durations. AMS for each station whose data were formatted were obtained by extracting the highest precipitation amount for a particular duration in each successive calendar year. AMS at stations formatted during this period were extracted for all durations equal to or longer than the base duration (or reporting interval) up to 60 days. The criteria for extraction were designed to exclude maxima if there were too many missing or accumulated data during the year, especially during critical months when precipitation maxima were most likely to occur. All annual maxima that resulted from accumulated data were flagged and screened to ensure that the incomplete data did not result in erroneously low maxima.

2.1.3. Station metadata screening

In this reporting period, we continue screening stations' metadata for errors. 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. Only stations that have failed two tests: elevation differences between the station metadata and DEM over 150 m and locations outside of the 1-minute precision box, were manually inspected for the metadata corrections. A total of 117 station locations were manually checked, and 101 adjustments were made in this project area so far. In the next reporting period, the team will continue to perform manual metadata inspection for other datasets formatted (Table 2).

2.1.4. Cleanup Visualization Dashboard

A dashboard, developed using Python, was designed to combine precipitation data from various co-located stations to create a unified series of annual maximum precipitation values while eliminating duplicate station records (Figure 8). The co-located stations were identified by matching their unique identifiers, such as WBAN ID, COOP ID, and GHCN ID.

The dashboard offers improved visualization capabilities and automates data entry, representing a significant upgrade over the older MATLAB code previously used for this purpose. The tool can also be used for the cleanup of stations within a radius.

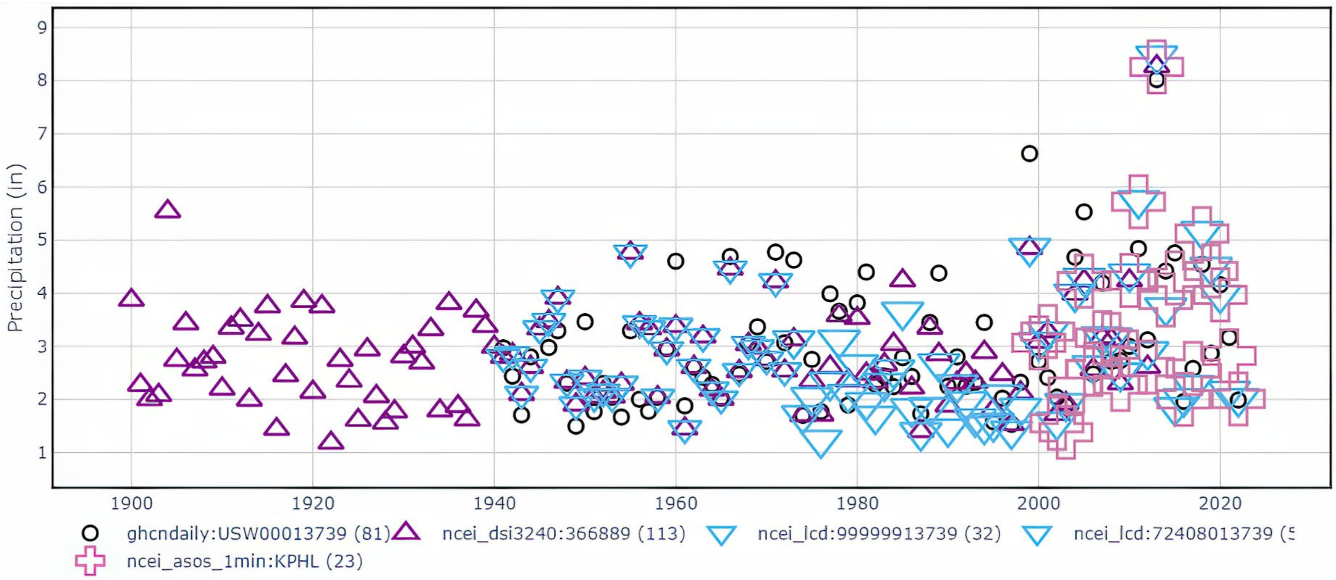

Figure 8. Dashboard visualization of all datasets that contain data for Philadelphia International Airport for the 1-day duration. These stations will be merged into a single time series at this location.

2.1.5. AMS quality control

The AMS data at both high and low extremities can considerably affect precipitation frequency estimates. Consequently, they need to be carefully investigated and either corrected or removed from the AMS if due to measurement errors. 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. For more information on what the QC visualization dashboard features, please refer to the previous July - Sept, 2023 Progress Report.

In this reporting period, the AMS quality control task for the 1-day duration of all NCEI GHCN-DAILY data has been completed, and the AMS quality control task on all hourly durations for the NCEI COOP stations has been initiated and is anticipated to be completed by the end of the next reporting period.

2.1.6. 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), can be incorporated into the parameter optimization process, allowing 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 stepwise multiple regression, we are attempting to determine the most critical covariates in this project area based on mean squared error and R^2. Our continuing analysis has demonstrated the ability to consistently achieve favorable results in this project area, even when excluding PRISM MAP as a covariate. Consequently, we are continuing our investigation in this direction. Additional spatial covariates were derived during this reporting period, including a "lake effect index" based on a location's proximity to long fetches of moisture in the westnorthwesterly direction. This variable significantly benefits the regression for locations near the Great Lakes.

Additionally, we explored the question of whether 30 arc seconds (~800 m) spatial resolution is necessary for spatial analysis of mean annual maximum (MAM) precipitation. We modified the stepwise multiple regression procedure to resample spatial covariates to a coarser resolution, performed the regression using the coarsened inputs, then compared the sampled background (i.e., fitted) MAM at the coarser resolution with the observed values. This coarsening of spatial covariates was performed for both 1-day and 1-hour MAM, for the full Volume 13 region. Figure 9 illustrates the result of this experiment. For 1-day MAM, significant degradation of the fitted result, expressed as a reduction in its R^2 value, begins around a resolution of 5 km, while for 1-hour MAM, this degradation begins at a much coarser resolution, around 50 km. The benefit of spatial resolution finer than 5 km is therefore not evident here, though the experiment has not been performed for durations longer than 1 day, for which a finer resolution may prove beneficial.

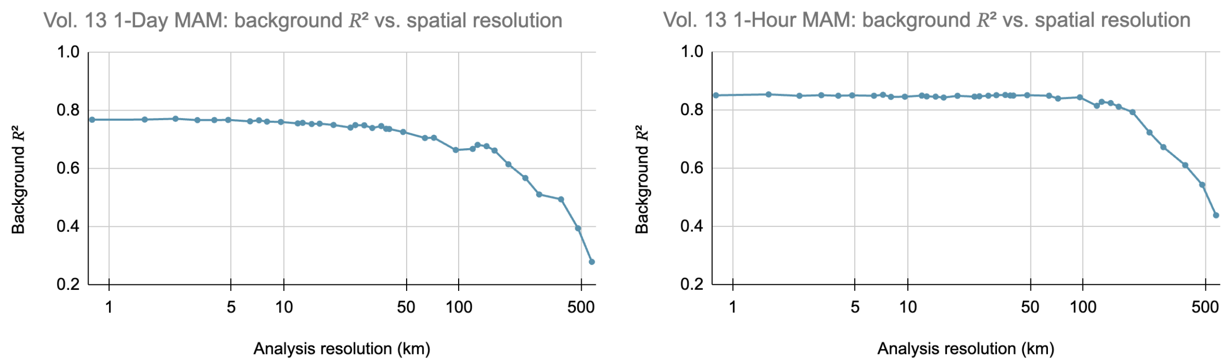

Figure 9. Coefficient of determination (R^2) of fitted mean annual maximum (MAM) precipitation vs. analysis resolution for 1-day and 1-hour AMS observations across the Volume 13 region.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2024)

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 evaluate the spatial covariates 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]
- 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. 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 HDSC team has been keeping various stakeholders updated on the progress of the Atlas 15 project. In this reporting period, Ed Clark, National Water Center Director, provided a briefing on Atlas 15 at the 2023 American Geophysical Union (AGU) Annual Conference in San Francisco on December 12, 2023.