Hydrometeorological Design Studies Center
Progress Report for Period
1 April 2022 to 30 June 2022

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 commenced work on a NOAA Atlas 14 Volume 12 for a full precipitation frequency analysis covering the states of Idaho, Montana and Wyoming, referred to as the Interior Northwest. The NOAA Atlas 14 Volume 12 precipitation frequency estimates are expected to be published by December 2023. Figure 1 shows the new project area as well as updated project areas included in NOAA Atlas 14, Volumes 1 to 12. For any inquiries regarding NOAA Atlas 14, please send an email to hdsc.questions@noaa.gov.

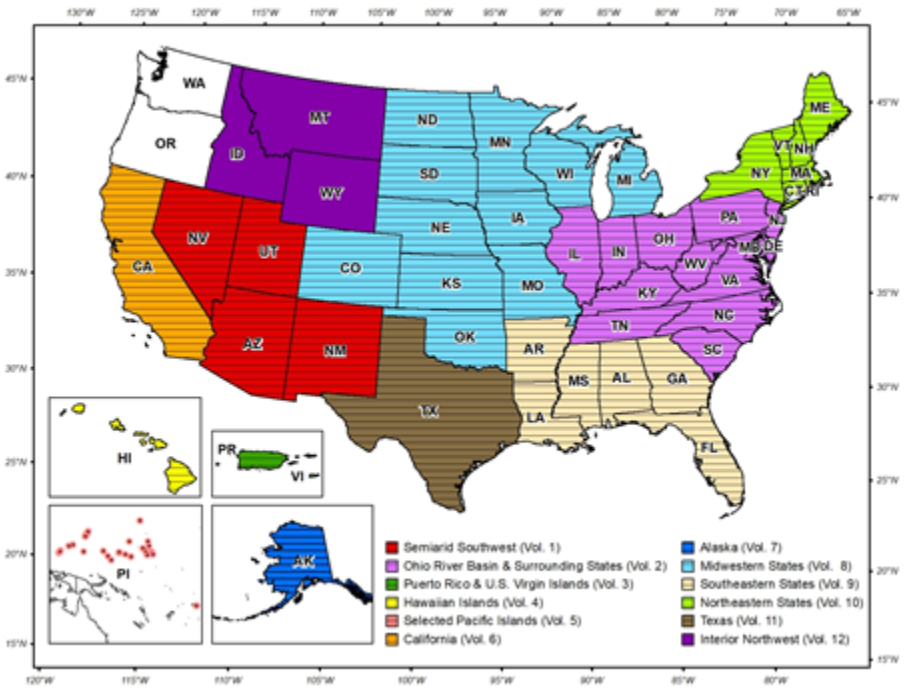

Figure 1. States or territories associated with each of the volumes of the Atlas.

II. CURRENT NOAA ATLAS 14 PROJECTS

2.1 VOLUME 12: INTERIOR NORTHWEST

On May 26, 2021, the HDSC commenced work on a new NOAA Atlas 14 Volume 12. The precipitation frequency estimates for this volume includes the states of Idaho, Montana and Wyoming with an approximately 1-degree buffer around these states (Figure 2). This project's planned completion date is December of 2023.

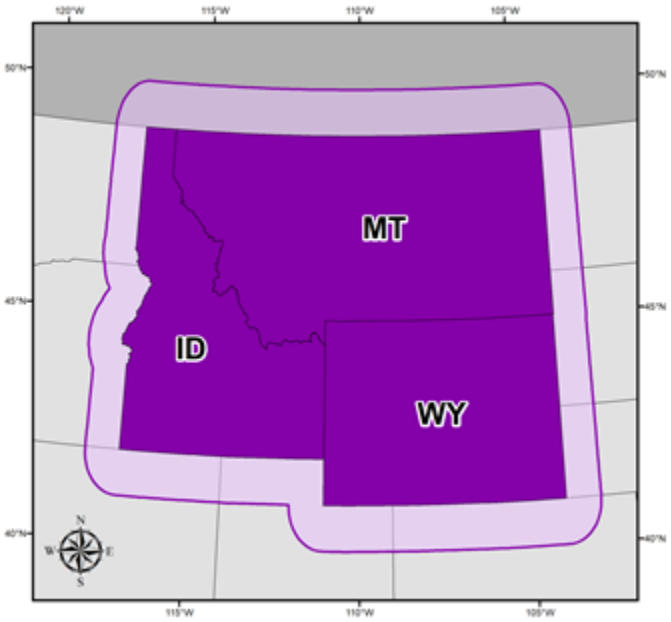

Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

During April, 1 2022 to Jun, 31 2022 reporting period, we worked on collecting and formatting additional datasets and completing related station screening and initiating the quality control tasks. The individual sections below describe in more detail the major tasks performed during this reporting period.

2.1 PROGRESS IN THIS REPORTING PERIOD (April - Jun 2022)

2.1.1. Data collection and data screening

The primary source of NOAA Atlas 14 Volumes 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. Since we started this project, we have contacted numerous agencies for assistance with the data and would like to thank all of those who responded to our inquiry and/or provided the data.

During this reporting period, we finished reviewing and formatting all the information provided to us. All data was formatted to a common format at one of three base durations (1-day, 1-hour, and 15-

minute) that corresponds to the original reporting period. Data recorded at n-minute or at variable time steps were formatted at 15-minute increments. Each formatted station was assigned a unique 6-digit identification number (ID), where the first 2 digits of the ID indicate the dataset. We have formatted and retained 15,596 stations from 34 datasets listed in Table 1. The total number of retained stations per recording period so far is listed in Table 3.

Table 1. Sources of datasets considered, contacted, downloaded or formatted for the precipitation frequency analysis for NOAA Atlas 14 Volume 12.

FID	Data Provider	Dataset name	Abbr.	Base Duration	Status
1	National Centers for Environmental Information (NCEI)	Automated Surface Observing System	ASOS	1M	formatted
2		DSI 3240, DSI 3260	DSI 3240, DSI 3260	15M, HLY	formatted
3		Global Historical Climatology Network	GHCN-DAILY	DLY	formatted
4		Environment Canada	GHCN-DAILY	DLY	formatted
5		Integrated Surface Data (Lite)	ISD_LITE	HLY, DLY	formatted
6		Local Climatological Data	LCD	HLY	formatted
7		Hourly Precipitation Data (HPD) v1.0 Beta and v2.0 Beta	HPDv1, HPDv2	HLY,15M	formatted
8		United States CoCORAHS	GHCN-DAILY	DLY	formatted
9		Canada CoCORAHS	GHCN-DAILY	DLY	formatted
10		Snow Telemetry	GHCN-DAILY	DLY	formatted
11		Weather Bureau Army Navy (WBAN)	GHCN-DAILY	DLY	formatted
12		U.S. Climate Reference Network (USCRN)	USCRN	5M, HLY, DLY	formatted
13	Ada County Highway District	Precipitation Gauge Network	AC	DLY, HLY, VARYING	formatted
14	Boise State University	Dry Creek Experimental Watershed	DCEW	HLY	formatted
15	City of Caldwell, Idaho	City of Caldwell	CC	DLY	formatted
16	Environment and Climate Change Canada	Historical Climate Data Network	EC	DLY, HLY, 15M	formatted
17	High Plains Regional Climate Center (HPRCC)	Automated Weather Data Network (AWDN)- CoAgMet, NDAWN, and WACNet	AWDN	DLY, HLY, 15M	formatted

FID	Data Provider	Dataset name	Abbr.	Base Duration	Status
18	Idaho National Laboratory (INL)	Air Resources Laboratory (ARL) Mesonet	INL_ARL	DLY, 5M	formatted
19	Idaho Power Company		IPC		contacted
20	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	DLY	formatted
21	National Atmospheric Deposition Program (NADP)	National Trends Network	NADP	DLY	formatted
22	National Weather Service (NWS)	Snowpack Telemetry (SNOTEL) Network	SNOTEL	DLY, HLY	formatted
23	North Dakota Atmospheric Resource Board	Cooperative Observer Network (ARBCON)	ARBCON	DLY	formatted
24	South Dakota University	South Dakota Mesonet	SD_MESONET	DLY, HLY	contacted
25	U.S. Bureau of Reclamation (USBR)	HydroMet	HYDROMET	DLY, HLY	formatted
26		Agricultural Weather Networks (AgriMet)	AGRIMET	DLY, 15M	formatted
27	University of Montana	Montana Mesonet	MT_MESONET	DLY	formatted
28	University of Utah Synoptic Data	MesoWest	MESOWEST	HLY	formatted
29	University of Wyoming Water Resources Data System	Wyoming Agricultural Climate Network	WACNet	DLY, HLY	formatted
30	U.S. Dept of Agriculture (USDA), Agricultural Research Service, The Northwest Watershed Research Center (NWRC)	Reynolds Creek Experimental Watershed Data (RCEW)	RCEW	DLY, HLY	formatted
31	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network (SCAN)	SCAN	DLY, HLY	formatted
32	U.S. Dept of Agriculture (USDA) Forest Service	Coram Experimental Forest	CEF	DLY	formatted
33	U.S. Dept of Agriculture (USDA) Forest Service	Priest River Experimental Forest	PREF	DLY	formatted
34	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network (RAWS)	RAWS	HLY	formatted

Table 2 contains information on additional datasets that will not be used in the analysis. They largely contain information already included in other datasets, or data assessed as not reliable for this specific purpose, or they contain only stations with short records unsuitable for merging with nearby stations.

Table 2. Additional datasets investigated.

Source of data and dataset/network name (if available)
Montana Department of Transportation- Engineering Division, Highways Bureau, Hydraulics Section Precipitation Study
NCEP Meteorological Assimilation Data Ingest System (MADIS)
U.S. Geological Survey (USGS): Nation Water Information System (NWIS)
Idaho National Engineering and Environmental Laboratory (INEEL) Network
Idaho Transportation Department (ITD) / Montana Department of Transportation: Road Weather Information Systems (RWIS)
University of Nebraska Lincoln: Nebraska Mesonet

The total number of retained stations per recording period so far is listed in Table 3.

Table 3. Number of stations per recording period.

Recording period	**Number of stations**
1-day	8,055
1-hr	6,679
15-min, n-min, varying	862
TOTAL	**15,596**

Locations of formatted daily stations are shown in Figure 3. Only stations with at least 30 years of useful data (shown as blue circles) will be considered for frequency analysis, although allowances may be made for isolated stations. Similarly, Figure 4 shows the locations of formatted stations recording at 1-hour (shown as red circles) and at sub-hourly (shown as green circles) durations, respectively, where stations have at least 20 years of useful data.

At the start of this project, we also contacted our network of users and stakeholders to help us identify the data sources in the project area. We would like to thank all of those who responded to our inquiry and/or provided the data. We welcome any information on the data for this project area. If you have any relevant information, please contact us at hdsc.questions@noaa.gov.

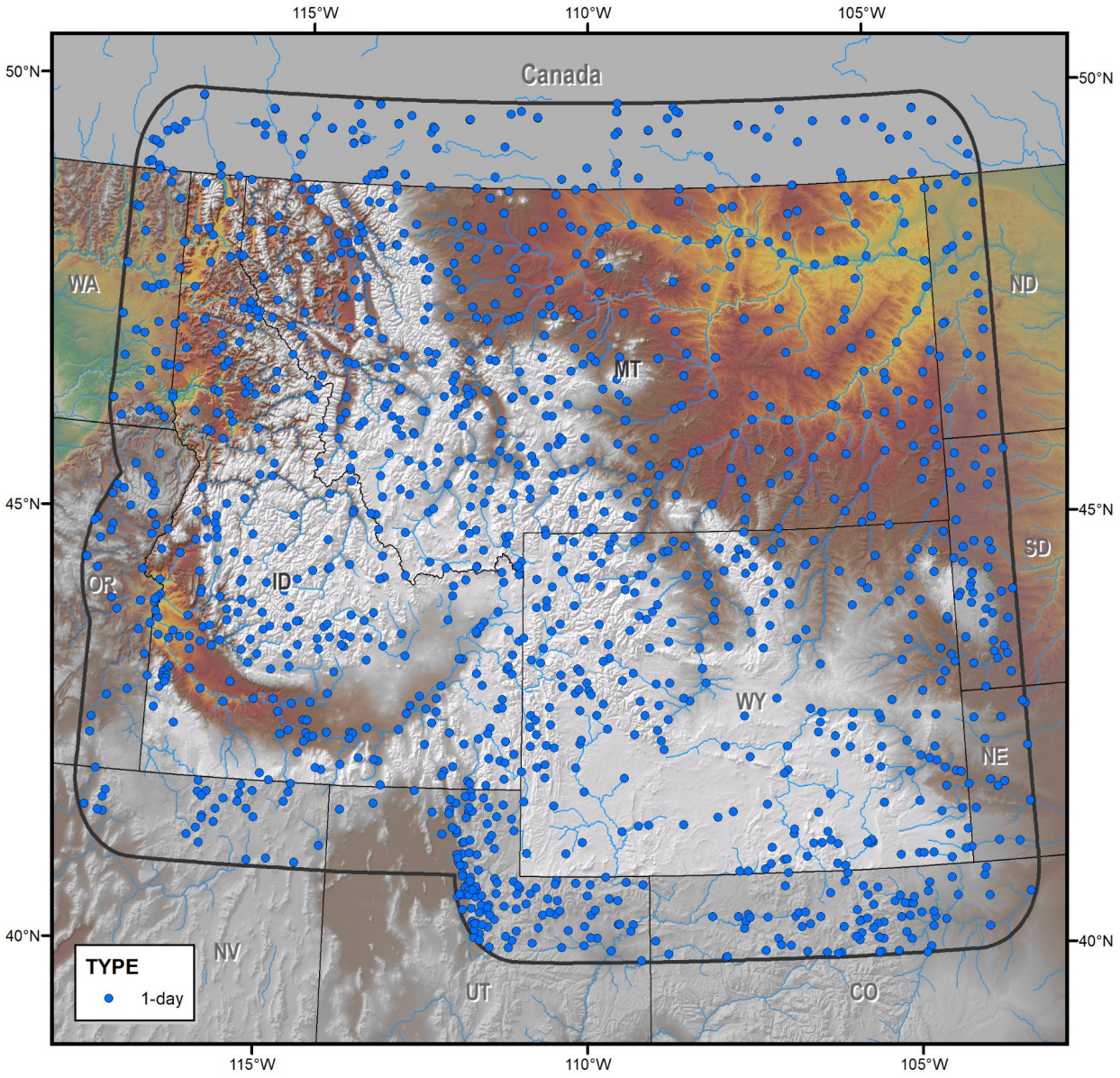

Figure 3. Map showing 1,399 formatted stations recording at 1-day interval with 30 years of data

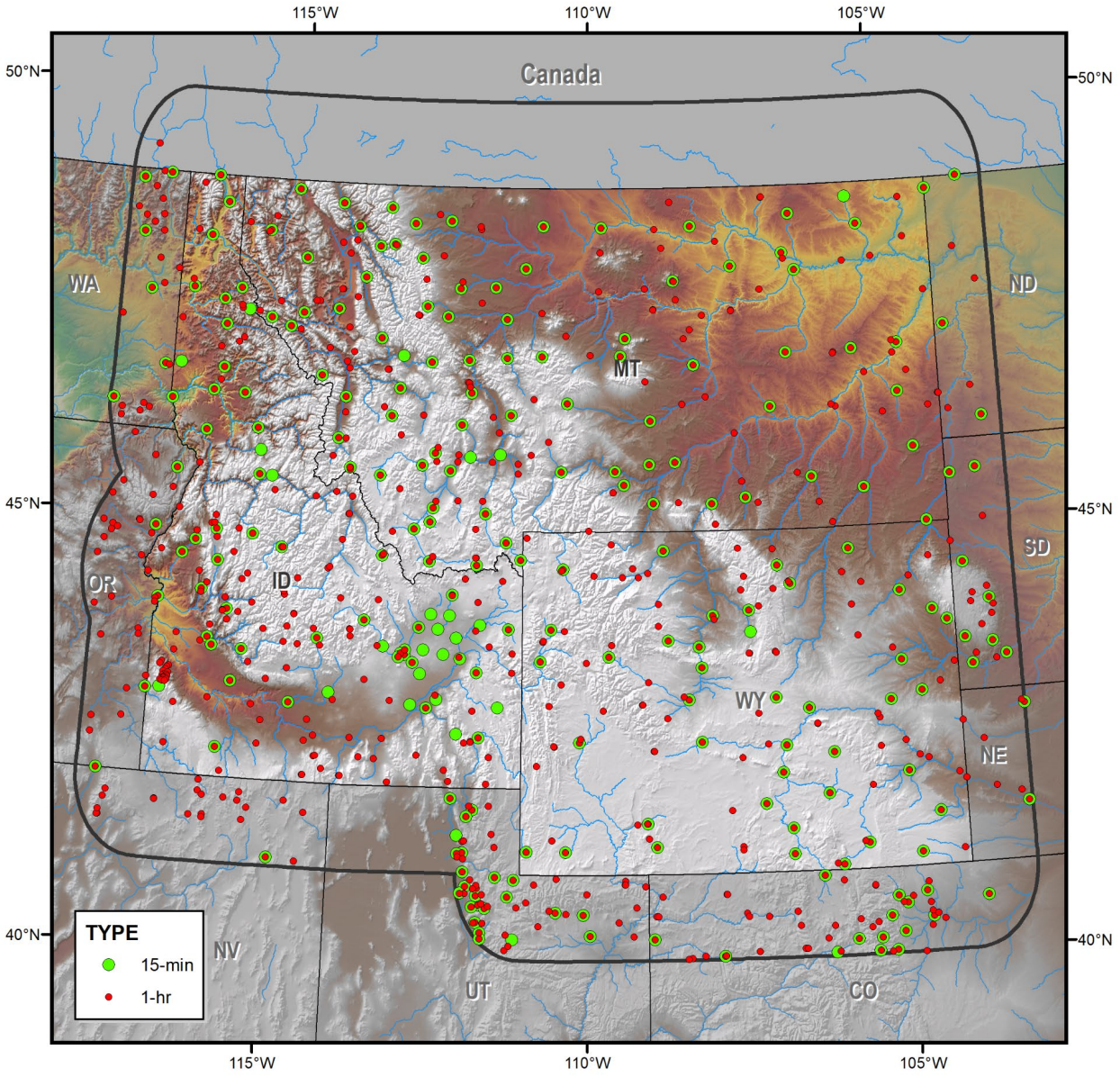

Figure 4. Map showing 778 formatted stations recording at 1-hour and 250 at 15-minute with at least 20-years of data.

2.1.2. Metadata quality control

We finished screening stations' metadata for errors and implemented all corrections for all formatted dataset. Original and revised coordinates for all stations used in the analysis will be provided in Appendix 1 of the accompanying NOAA Atlas 14 Volume 12 document. Stations with no elevation information were assigned DEM elevations and also investigated for possible location errors.

2.1.3. Station cleanup

In this reporting period, we completed and implemented changes from the second round of cleanup, which looked at all stations within a 3-km radius. As a result of the station cleanup task since the start of the project, we implemented 7844 deletes and 1179 data merges and/or extensions.

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 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

Additional smaller cleanup rounds were conducted on individual datasets that were reformatted or such as SCAN dataset, which had multiple precipitation variables which needed to be reformatted or USBR dataset which needed to be cleaned separately first to remove erroneous values and delete unreliable stations before any data could be potentially merged with other datasets. Due to significant data quality issues, snotel hourly values above 1-inch in winter months were automatically removed before those stations were included in any cleanup rounds with other datasets. To reduce the number of stations in certain large datasets that tend to be less reliable and useful, Mesowest and CoCoRaHS stations with the short records (less than 4 years) were automatically removed.

2.1.4. 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.

2.1.5. AMS quality control

Since AMS data at both high and low extremities can considerably affect precipitation frequency estimates, they have to be carefully investigated and either corrected or removed from the AMS if due to measurement errors.

In this reporting period, we started the daily AMS quality control task. We use different statistical tests to identify high and low outliers in the distribution of at-station precipitation AMS. All identified outliers and other questionable maxima at base durations (1-hour and 1-day) are now being verified. First, they are mapped with concurrent measurements at nearby stations. If the values cannot be confirmed from similar measurements at nearby stations, they are investigated further using information from monthly climatological data publications, cooperative observation forms, and monthly storm data reports obtained primarily from the NCEI's Image and Publication System (IPS). Additional resources such as historical storm reports and surface weather observations are accessed through NCEI's Environmental Document Access and Display System, Version 2 (EV2) application. Gridded precipitation products and other NEXRAD radar products are also used in some cases to verify and help disprove events for areas with good radar coverage.

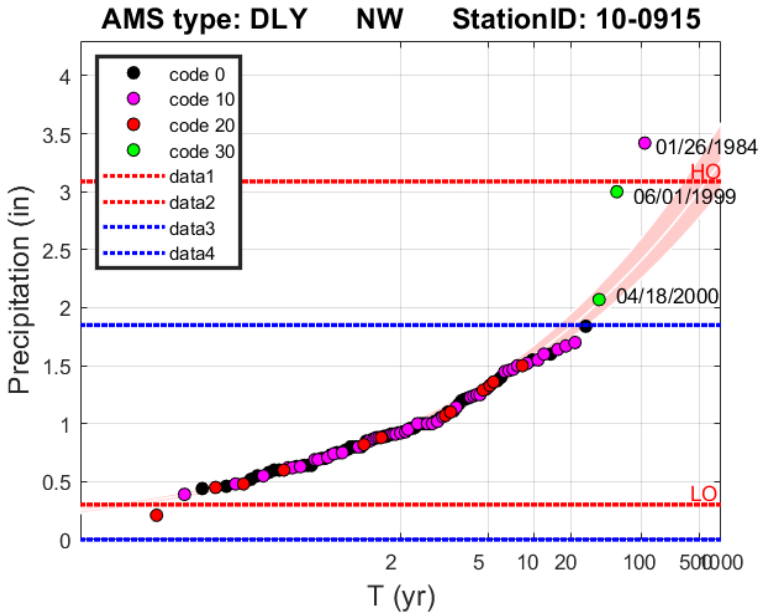

Figure 5: Example of long record daily station in Idaho (Blackfoot, 10-0915) with the top 3 highest 1-day values in the official record all being erroneous values

Issues encountered while quality controlling the annual maximum time series for the Volume 12 project area:

a) COOP form availability - Scanned copies of the original observer forms for Idaho are mostly missing before 1980 as well as a substantial quantity missing before 1980 for Montana. These forms are essential for confirming high outlier events and disproving suspect values.

b) Snowfall values digitized as precipitation amounts, usually when the observer incorrectly puts snowfall in the precipitation column or switches precipitation and snowfall in opposite columns for the entire month.

c) Data quality over time - some stations with long continuous records have degraded data quality in the last 10-20 years (as seen in the below example of station 10-2892 DLY). Often this is related to the transition to digital observation forms (eg. wxcoder).

d) Accumulated precipitation values are often digitized as single day values, of which many are not correctly marked as accumulations by the observer on the COOP forms. Observers often don't enter zero precipitation days, which makes it difficult to discern between truly missing values, dry days, and multi-day accumulations. Occasionally observers will even put zero values incorrectly for days that should be marked as multi-day accumulations instead. This issue of accumulated values is also evident in the example of 10-2892.

e) Modern COOP forms are either typed or values entered electronically which makes it harder to identify digitization errors and disprove a value if it entered incorrectly. If an observer makes a typographic error entering a value, that value can't be interpreted because there's no handwritten form to verify the value.

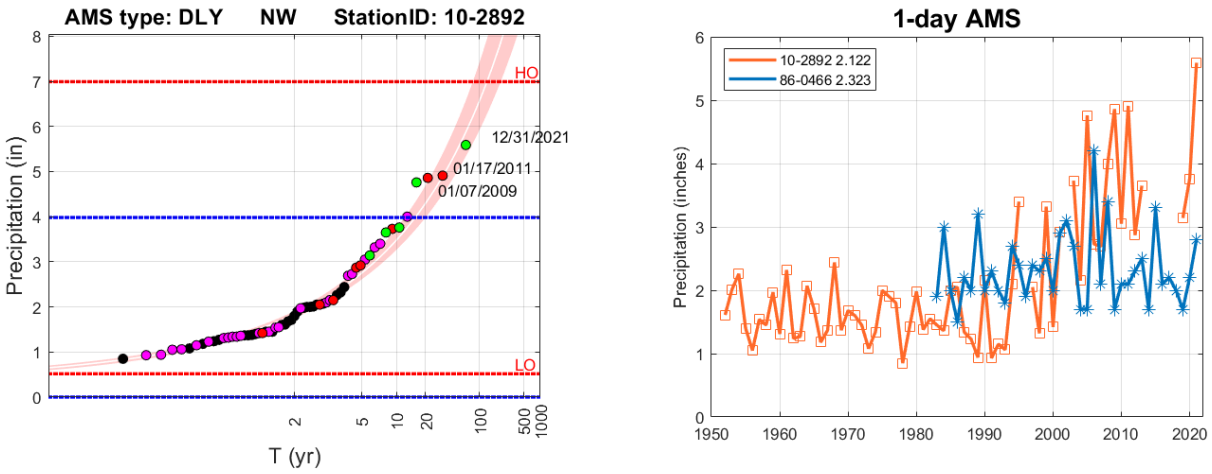

Figure 6: a) 1-day distribution plot for 10-2892 with many data quality issues b) 1-day time series comparison of 10-2892 with the closest SNOTEL station

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (July - Sep 2022)

We will continue with quality control checks for the base duration (1-day, 10-day, and 1-hour) for all the stations retained after the cleanup task. The large portion of the work in the next reporting period will be on finalizing AMS extraction and working on quality control of AMS data. Work will begin on climate region development, and developing the mean annual maxima (MAM) grid in collaboration with the PRISM Group from Oregon State University.

2.3. 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)] [In progress; revised to October 2022]
- Regionalization and frequency analysis [Revised to November 2022]
- Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [November 2022]
- Peer review [January 2023]
- Revision of PF estimates [March 2023]
- Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [September 2023]
- Web publication [December 2023]

III. OTHER

3.1. ANALYSIS OF IMPACTS OF NON-STATIONARY CLIMATE ON NOAA ATLAS 14 ESTIMATES

On February 7, 2022, a document titled “Analysis Of Impact Of Non-stationary Climate On NOAA Atlas 14 Estimates: Assessment Report“ was posted on an OWP website. This scientific document describes the research conducted in collaboration between HDSC and Penn State University, University of Illinois, and University of Wisconsin academic research teams. It provides recommendations on a new modeling framework allowing non-stationary climate effects to be integrated into the NWS’s precipitation frequency products.

The enacted Infrastructure Investment and Jobs Act (IIJA) provides a level of support for precipitation frequency studies. For additional details about IIJA support, please see the NOAA press release: https://www.noaa.gov/infrastructure-law/infrastructure-law-climate-data-and-services/flood-and-inundation-mapping-and-forecasting.

The HDSC is considering the generation of two volumes: one that utilizes historical observations within a non-stationary framework and another that incorporates climate projects. The HDSC group plans to solicit feedback and comments on the proposed upgrade through the NWS’ National Service Change Notices and Public Statements, that would be available on the following webpage: https://www.weather.gov/notification/.

3.2. ARTICLES, CONFERENCES, MEETINGS

HDSC’s Acting Technical Director Sandra Pavlovic presented the Next Generation of the Precipitation Frequency Estimates at the 2022 AWRA Spring Conference in Tuscaloosa, Alabama, on April 26, 2022.

HDSC’s Sandra Pavlovic attended the 2022 Montana Stormwater Conference in Missoula, Montana, and gave a presentation titled: “NOAA Atlas 14 Volume 12, Precipitation Frequency Estimates Update for Interior Northwest” on May 2, 2022.

HDSC’s Michael St.Laurent and Sandra Pavlovic gave a 30-minute presentation titled:” NOAA National Precipitation Frequency Updates” at the Great Lakes Water Infrastructure Virtual Conference on May 10, 2022. This presentation provided an overview of the current NOAA Atlas 14 estimates and proposed a plan to update the estimates using the updated methodology as a seamless national analysis.

On May 6, 2022, HDSC’s Sandra Pavlovic gave a 30-minute briefing on the NOAA Atlas 14 and proposed non-stationary modeling framework to Association of State Floodplain Managers (ASFPM) technical leadership. The presentation for the larger ASFPM audience is scheduled for July 21, 2022.

HDSC’s Sandra Pavlovic and Michael St.Laurent gave a presentation to The OWP All-Hands meeting on June 1, 2022 on NOAA Atlas 14 Vol 12 and future development plans.