Hydrometeorological Design Studies Center

Progress Report for Period
1 October 2021 to 31 December 2021

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 and Montana. The NOAA Atlas 14 Volume 12 precipitation frequency estimates are expected to be published by December 2023. No funding is available to extend NOAA Atlas 14 Volume 12 coverage to the remaining three northwestern states: Oregon, Washington and Wyoming. 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.

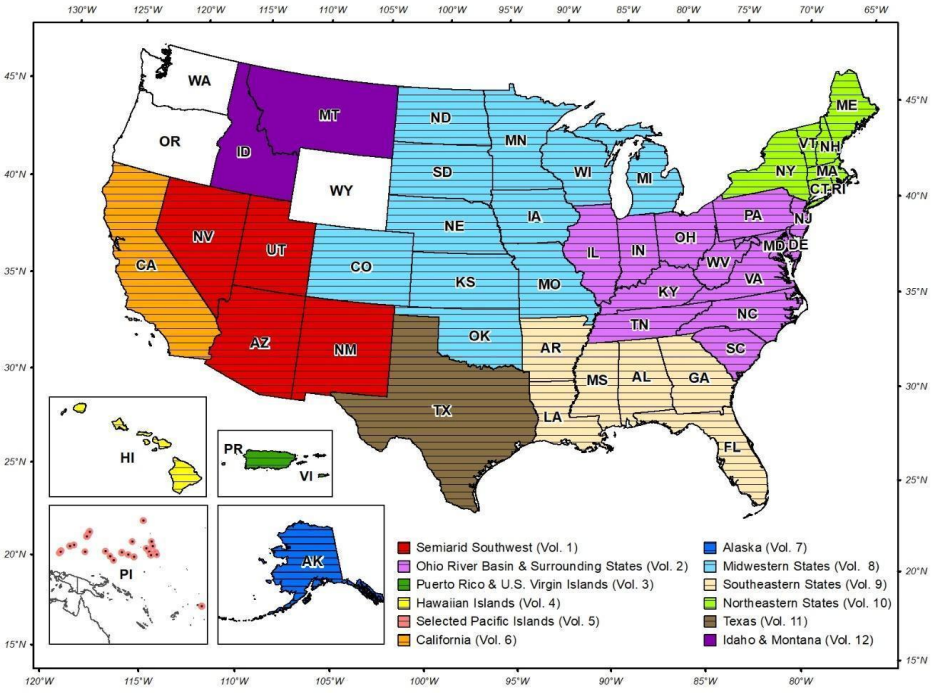


Figure 1. States or territories associated with each of the volumes of the Atlas.

II. CURRENT NOAA ATLAS 14 PROJECTS

1. VOLUME 12: IDAHO AND MONTANA STATES

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 Montana and Idaho and approximately a 1-degree buffer around these two states (Figure 2). This project's planned completion date is December of 2023.

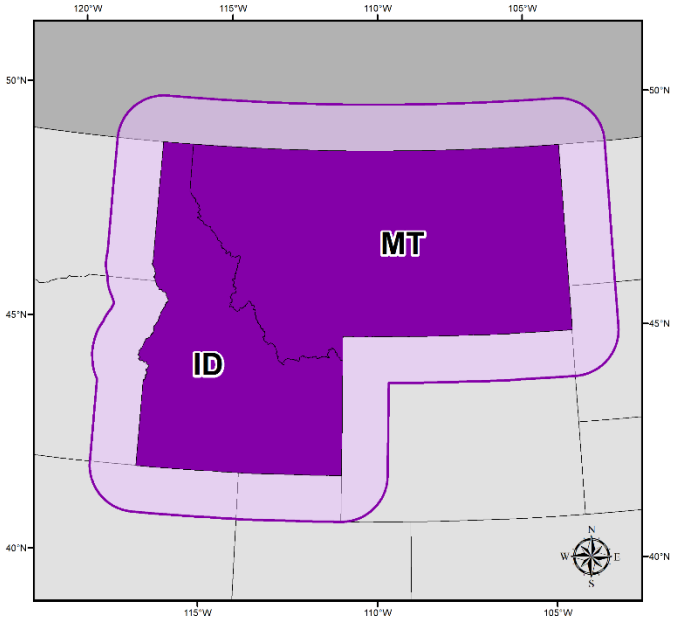


Figure 2. NOAA Atlas 14, Volume 12 extended project area (shown in purple).

During October, 1 2021 to December, 31 2021 reporting period, we worked on collecting and re-formatting additional datasets and completing related station screening and initial quality control tasks. The individual sections below describe in more detail the major tasks performed during this reporting period.

1.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2021)

1.1.1. 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.

For this project area, we are interested in collecting all available precipitation datasets (daily, hourly, 5-minute, etc.) for stations in Idaho and Montana, as well as in adjacent portions of neighboring states (Nevada, North Dakota, Oregon, South Dakota, Utah, Washington and Wyoming) and also in Canada.

In this reporting period, we continued to download and format the 15-minute, hourly and daily datasets we received, and we continued to contact data providers of the newly identified datasets. We also extended the collection and formatting of the datasets previously identified to include the gauge stations for the whole state of Wyoming, including this state's 1-degree buffer into the neighboring states. Table 1 lists all sources of data collected so far and the current status of the data formatting task.

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		Quality Controlled Local Climatology	QCLCD	HLY	formatted
7		Unedited Local Climatological Data	ULCD	HLY	formatted
8		Hourly Precipitation Data (HPD) v1.0 Beta and v2.0 Beta	HPDv1, HPDv2	HLY,15M	formatted
9		United States CoCORAHS	GHCN-DAILY	DLY	formatted
10		Canada CoCORAHS	GHCN-DAILY	DLY	formatted
11		Snow Telemetry	GHCN-DAILY	DLY	formatted
12		Weather Bureau Army Navy (WBAN)	GHCN-DAILY	DLY	formatted
13		U.S. Climate Reference Network (USCRN)	USCRN	5M, HLY, DLY	considering

FID	Data Provider	Dataset name	Abbr.	Base Duration	Status
14	Ada County Highway District	Precipitation Gauge Network	AC	DLY, HLY, VARYING	received
15	City of Caldwell	City of Caldwell	CC	DLY	received
16	Environment Canada (EC)		EC	DLY, HLY, 15M	re-formatting
17	High Plains Regional Climate Center (HPRCC)	Automated Weather Data Network (AWDN)- CoAgMet, NDAWN, and WACNet	AWDN	DLY, HLY, 15M	received
18	Idaho National Laboratory (INL)	Air Resources Laboratory (ARL) Mesonet	INL_ARL	DLY, 5M	received
19	Midwestern Regional Climate Center (MRCC)	CDMP 19th Century Forts and Voluntary Observers Database	FORTS	DLY	formatted
20	Montana Department of Transportation (MDT)	Engineering Division, Highways Bureau, Hydraulics Section Precipitation Study	MT_DOT	HLY	duplicate of NCEI
21	Montana Department of Transportation (MDT)	Road Weather Information System (RWIS)	RWIS	5M	considering
22	National Atmospheric Deposition Program (NADP)		NADP	DLY	contacted
23	National Centers for Environmental Prediction (NCEP)	Meteorological Assimilation Data Ingest System (MADIS)	MADIS	DLY, HLY, VARYING	duplicate
24	National Weather Service (NWS)	Hydrometeorological Automated Data System	HADS	HLY	received
25	National Weather Service (NWS)	Snowpack Telemetry (SNOTEL) Network	SNOTEL	DLY, HLY	received
26	North Dakota Atmospheric Resource Board	Cooperative Observer Network (ARBCON)	ARBCON	DLY	received
27	The Northwest Watershed Research Center (NWRC)	Reynolds Creek Experimental Watershed Data (RCEW)	RCEW	DLY, HLY	formatted
28	South Dakota University	South Dakota Mesonet	SD_MESONET	DLY, HLY	contacted

FID	Data Provider	Dataset name	Abbr.	Base Duration	Status
29	U.S. Bureau of Reclamation (USBR)	HydroMet	HYDROMET	DLY, HLY	received
30	U.S. Bureau of Reclamation (USBR)	Agricultural Weather Networks (AgriMet)	AGRIMET	DLY, 15M	received
31	U.S. Geological Survey (USGS)	Nation Water Information System (NWIS) dataset	NWIS	15M	not used
32	University of Montana	Mesonet	UM_MESONET	DLY	received
33	University of Utah Synoptic Data	MesoWest	MESOWEST	HLY	formatted
34	U.S. Dept of Agriculture (USDA)	Benton County Gauging Dam Data	BC	HLY	received
35	U.S. Dept of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Soil Climate Analysis Network (SCAN)	SCAN	DLY, HLY	received
36	U.S. Dept of Agriculture (USDA), Forest Service	Remote Automated Weather Station Network (RAWS)	RAWS	HLY	formatted

Locations of formatted daily, hourly and 15-minutes stations are shown in Figure 3. Daily stations are shown as blue circles, hourly as red, and 15-minutes as green circles. Only stations with at least 30 years of useful daily data and at least 20 years of useful hourly and sub-hourly data will be considered for the development of NOAA Atlas 14 estimates. However, these stations will be filtered after all the additional datasets have been added and the quality control and cleanup procedures (described in the sections below) are completed.

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.

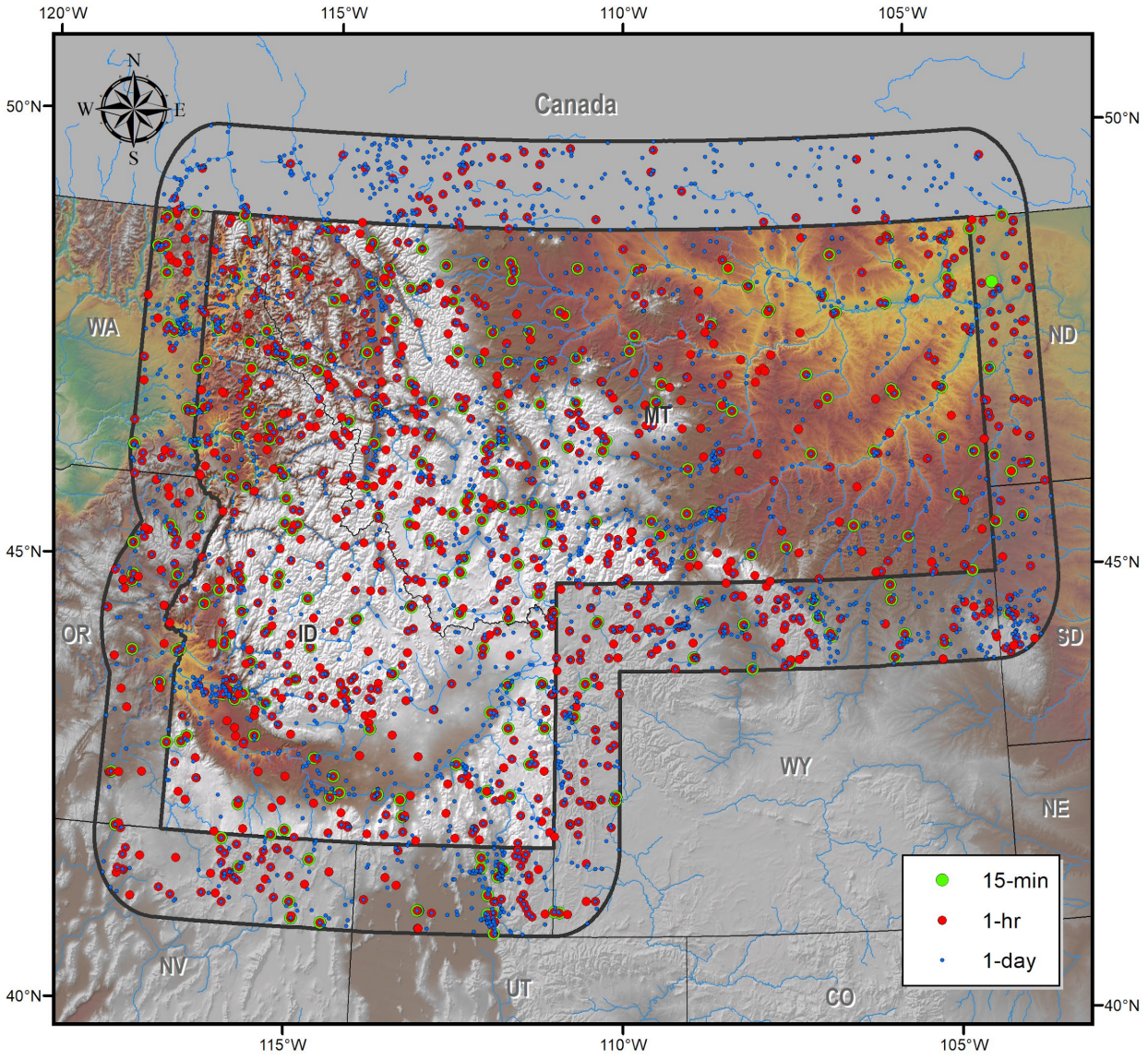


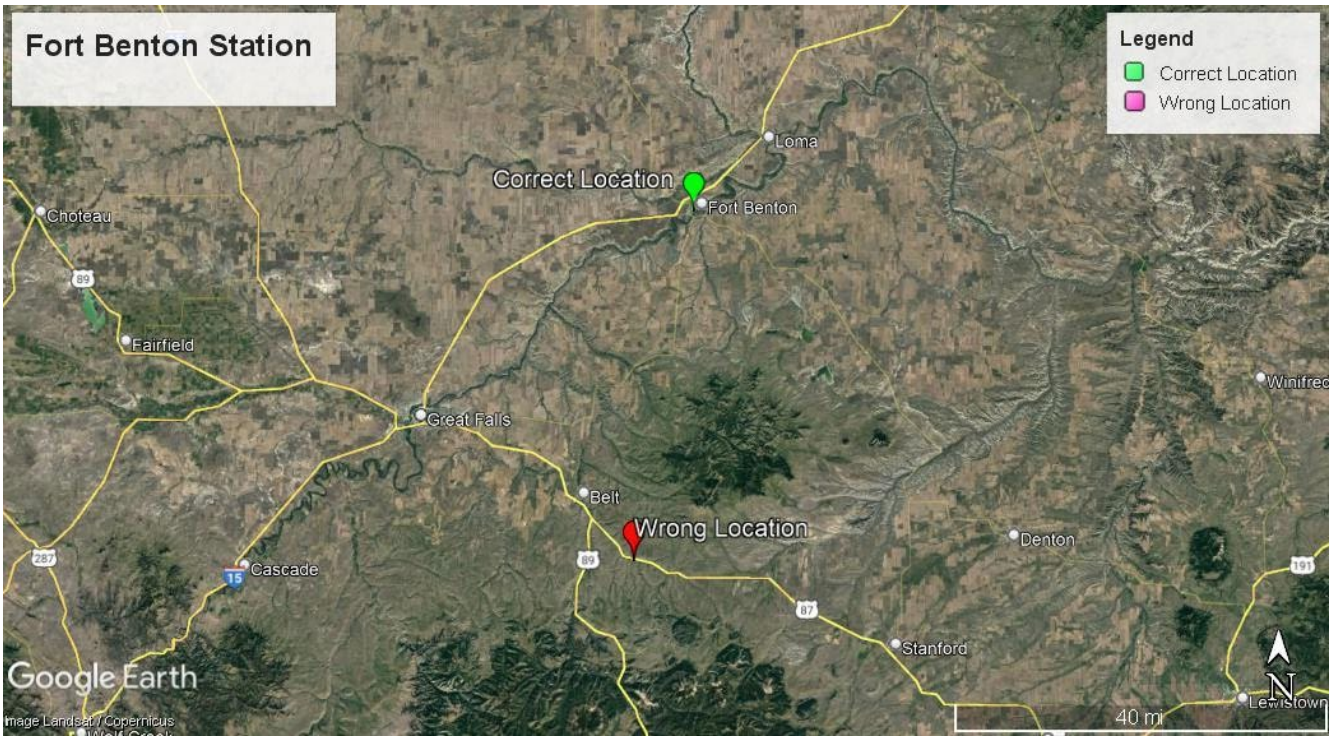
Figure 3. Map showing 3,539 formatted stations recording at 1-day interval, 1,453 at hourly and 415 at 15-minutes.

1.1.2. Metadata quality control

We finished screening stations' metadata for errors and implemented all corrections. In this reporting period, we screened the metadata information from additional datasets considered: INL Mesonet, Mesowest, RAWS, RCEW, EC, AWDN and FORTS. In this task, stations with potential errors were identified by reviewing published coordinates and elevations for large changes over the course of the station's lifetime. Stations with assigned elevations that were more than 10% different from elevations extracted from a 1 arcsecond (approx. 30 meters) digital elevation model (DEM) are being investigated. Such stations may be relocated based on inspection of satellite images, maps and records of the station's history. Misplacements were typically the result of latitude and longitude data

having inadequate precision. 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.

The example below shows a station Fort Benton, MT from the FORTS dataset. The location in red was the provided latitude/longitude.



BENTON (FORT BENTON), MONTANA.

Latitude..... 47° 51′
Longitude..... 110° 40′
Elevation of barometer above mean sea-level..... 2,700 feet.

Established October 11, 1879.
Office, Record building, corner of Main and Baker streets.

Figure 4. The FORTS Fort Benton, MT, station metadata (latitude, longitude information) correction example

Figure 4 top shows a station correction for the FORTS dataset. The station Fort Benton was moved 38 miles to the correct location and elevation was adjusted. Bottom shows an excerpt from the book, “Annual Reports of the War Department, Volume 4,” By the United States War Department, 1881, pg. 232 that was used to help determine the correct location of the station.

1.1.3. Station cleanup

In this reporting period, we implemented changes from the first round of co-located cleanup, and prepared the files to begin work on the 1-mile station cleanup for the NCEI’s stations’ (which make up the majority of the data for the project). In this reporting period, we extended the first round co-located cleanup effort to the whole state of Wyoming, and revisited a list of co-located cleanup cases for additional investigation. The result of an additional investigation effort includes adding a significant hourly event into the time-series data for Billings International Airport, MT, location.

A large discrepancy in 1997 was noted at daily durations after investigating large discrepancies between two stations' annual maximum series (AMS) measuring at different intervals at Billings International Airport, MT. Figure 5 highlights this difference at 2-day where 3.11 inches was captured by the daily gauge versus 1.62 inches at the hourly gauge. Further investigation revealed that a 2.91 inches event caught by the daily gauge on June 8th, 1997 was mostly missed by the hourly gauge. The hourly gauge aggregated measurement for the 24 hours (midnight to midnight local time) totaled 0.68 inches, making a difference of 2.23 inches between these two time series.

Further investigation was then done into the Billings International Airport, MT station because the hourly gauge significantly under-reported the event on June 8. Upon reviewing METARs for Billings International Airport, the rainfall began at 01:24Z on June 9th and continued until 6:56Z, which means the bulk of the rainfall on that evening fell in just under 6 hours. Since we know that very little rainfall fell during this day, confirmed by radar data and METAR reports from earlier on the day, an estimated 2.86 inches fell in 6 hours from 6-pm to midnight on the evening of June 8th. This is supported by storm data of this event, including this AP news report which states that "2 to 4 inches of rain fell Sunday evening." After adding this event back in, the new 12-hour AMS for 1997 is now 2.86 inches, second behind the May 24, 2011 event of 3.03 inches. More importantly, due to this correction, the 6-hour AMS of 2.86 for this event is the largest event in the record at this station going back to 1949, exceeding the 2.70 inches measured in the 2011 event.

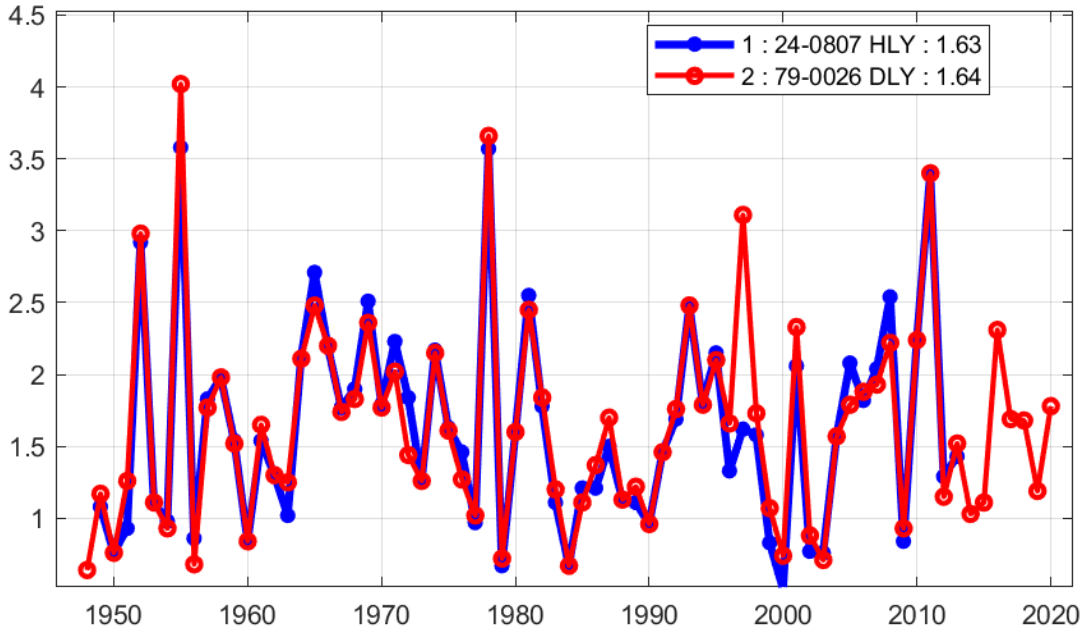


Figure 5: 2-day AMS plot highlighting the discrepancy between daily (79-0026) and co-located hourly station (24-0807) at Billings International Airport, MT.

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

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - March 2022)

We will continue with data collection, reformatting, station metadata, and quality control checks for NCEI and non-NCEI stations. All collected data will be examined and formatted into a common format, where appropriate.

The large portion of the work in the next reporting period will be on non-NCEI dataset reformatting and 1-, and 5-mile station cleanup.

Station cleanup investigation involves reviewing time series plots of annual maxima at 1-hour and 1-day co-located stations. 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.

1.3. PROJECT SCHEDULE

- Data collection, formatting, and initial quality control [March 2022]
- 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) [May 2022]
- Regionalization and frequency analysis [August 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

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

The work on the project to assess the impact of a non-stationary climate on the NOAA Atlas 14 method was put on hold from May, 2020 until May, 2021. In late May 2021, the HDSC resumed work on the non-stationary analysis. A draft analysis and assessment report by OWP has been completed, which includes the final reports from the university research teams. On Wednesday December 1, HDSC's Acting Technical Lead Sandra Pavlovic gave a presentation titled: "Analysis of Impact of Non-stationary Climate on NOAA ATLAS 14 Estimates: Assessment Report" to the DOT-FHWA. We plan to share the final assessment report in January 2022.

2. ARTICLES, CONFERENCES, MEETINGS

On Wednesday October 20, HDSC's Michael St. Laurent gave a presentation for the Greater Miami River Watershed's Network Meeting titled: "NOAA Atlas 14: Background, Applications and Future"

In November, Carl Trypaluk and Dale Unruh contributed an article titled "NOAA Atlas 14: Precipitation Frequency Estimates for the United States," for The Office of Water Prediction's newsletter- The Confluence: Year in Review. This article summarized recent HDSC activities including the report on Non-stationarity and recent work on developing precipitation frequency estimates for Volume 12. This newsletter is sent out to NOAA and OWP stakeholders each year.