HYDROMETEOROLOGICAL DESIGN STUDIES CENTER

QUARTERLY PROGRESS REPORT

1 October 2013 to 31 December 2013

Office of Hydrologic Development

National Weather Service

National Oceanic and Atmospheric Administration

U.S, Department of Commerce

Silver Spring, Maryland

January 2014

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 Hydrologic Development of National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) is updating precipitation frequency estimates for various parts of the United States and affiliated territories. Updated precipitation frequency estimates for durations from 5 minutes to 60 days and average recurrence intervals between 1- and 1,000-years, accompanied by additional relevant information (e.g., 95% confidence limits, temporal distributions, seasonality) are published in NOAA Atlas 14. All NOAA Atlas 14 products and documents 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. HDSC is currently updating estimates for the following northeastern states that will be published in 2015 as Volume 10: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Figure 1 shows the states or territories associated with each of the Volumes of the Atlas.

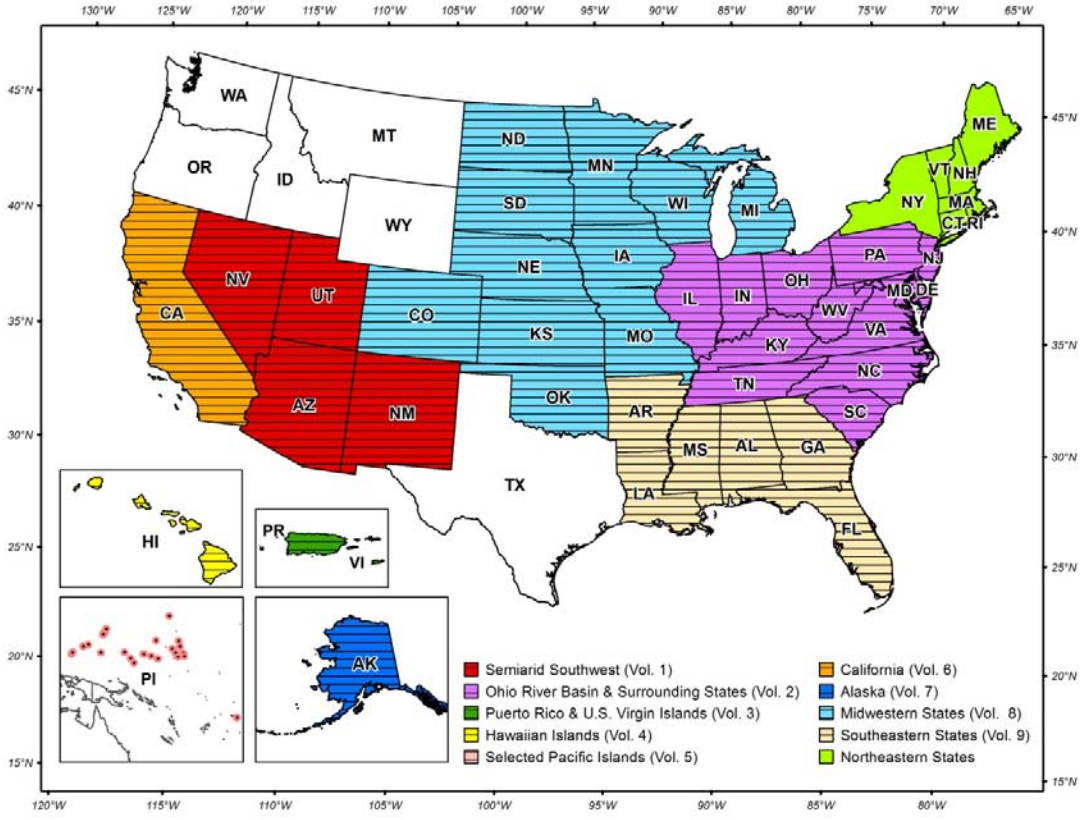

Figure 1. Current project area and project areas included in published NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2013)

The project area includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont, and approximately a 1-degree buffer around these states (Figure 2).

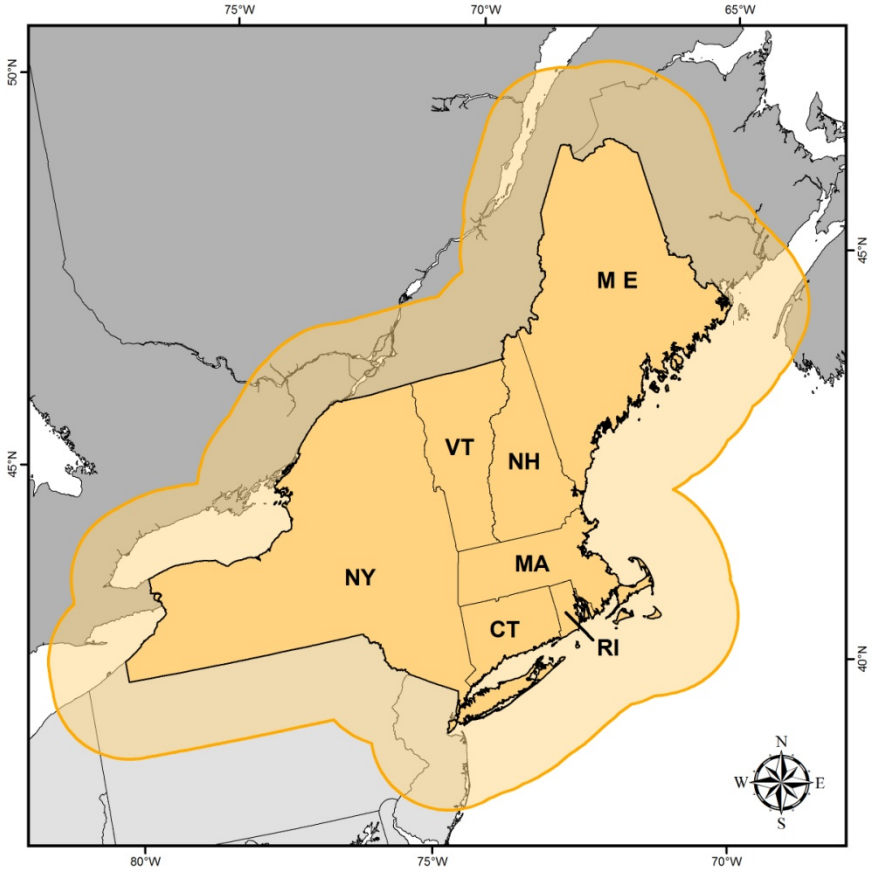

Figure 2. Northeastern precipitation frequency project area (shown in orange).

During this reporting period, significant progress has been made on annual maximum series extraction, station screening and quality control tasks. While most of the work on the data collection and formatting tasks has been completed during previous reporting periods, we are still collecting data, particularly for the areas that do not have good coverage, such as Maine. **If you know about any dataset in addition to those listed in Table 1 below, particularly in areas of low station density (see Figure 3 and 4 below for station coverage at daily and sub-daily durations, respectively), please contact us at HDSC.Questions@noaa.gov.** The individual sections below describe in more detail, major tasks performed during this reporting period.

1.1.1. Data collection and formatting

During this reporting period we

- collected Earth Networks data;
- collected and formatted Integrated Flood Observing and Warning System (IFLOWS) data from the NWS Mid-Atlantic River Forecast Center;
- formatted data from the New Hampshire Department of Transportation;
- finished digitizing scanned observation forms for selected stations from the Massachusetts Department of Conservation and Recreation dataset. Selected stations have long records and/or are located in areas where data coverage is inadequate;
- re-formatted NCDC hourly data to accommodate changes in NCDC missing flags;
- updated NCDC daily, hourly, and 15-minute data to include the most recently released data.

Table 1 lists all sources of data collected so far and the current status of the data formatting task. Datasets which were investigated, but will not be used in frequency analysis, are also listed in the table, together with a short explanation on why they will not be retained.

Table 1. Sources of data for the precipitation frequency analysis for NOAA Atlas 14 Volume 10. The last eleven datasets were investigated but will not be used for various reasons.

Source	Reporting interval	Preliminary number of stations	Formatting status and comments
Automated Surface Observing Systems (ASOS)	1-minute	42	formatted
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)	1-day	2,637	formatted (however, many stations only have a few years of data)
Boston Water and Sewer Commission	5-minute 15-minute 1-hour	6	formatted
Earth Networks	variable	~ 1,324	received
Environment Canada	1-day 1-hour	2,980 536	formatted
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	1-day	62	formatted
Massachusetts Department of Conservation and Recreation (DCR)	1-day	176	received data on CD; data for relevant stations digitized and formatted
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	variable	336	formatted data to 1-hour and 1-day
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	1-day	63	formatted

Source	Reporting interval	Preliminary number of stations	Formatting status and comments
Mount Washington Observatory	1-hour 1-day	1	sent inquiry
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	1-day 1-hour 15-minute n-minute	3,001 593 517 43	formatted
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC): U.S. Climate Reference Network (USCRN)	1-day 1-hour	11 11	formatted
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	1-day	1	formatted
New Hampshire Department of Transportation	15-minute	15	formatted
Office of the New Jersey State Climatologist at Rutgers University: NJ Mesonet	variable	7	received data via email; formatted
Office of the New Jersey State Climatologist at Rutgers University: NJ SafetyNet	variable	5	received data via email; formatted
U.S. Department of Agriculture: Agricultural Research Service (ARS)	variable	23	missing elevation in metadata; formatted
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	1-hour	40	formatted
USGS Maine Water Science Center	1-day 15-minute	16 n/a	formatted
USGS Massachusetts-Rhode Island Water Science Center	1-day hourly 15-minute	5 1 16	formatted
USGS New Hampshire-Vermont Water Science Center	1-day 15-minute	6 n/a	formatted
USGS New York Water Science Center	1-day	1	formatted
Citizen Weather Observers Program	n/a	n/a	data have short records
DATASETS THAT WILL NOT BE USED IN FREQUENCY ANALYSIS:			
Connecticut ALERT Network/ Automated Flood Warning Systems (AFWS)	variable	n/a	network discontinued; no suitable archived dataset available

Source	Reporting interval	Preliminary number of stations	Formatting status and comments
Cornell University: Network for Environment and Weather Applications (NEWA)	1-hour	n/a	data have short records and limited quality assurance
Global Summary of the Day (NCDC)	1-day	n/a	data are duplicate of NCDC and Environment Canada data
NOAA Earth Systems Research Laboratory - Meteorological Assimilation Data Ingest System (MADIS)	various	n/a	data are a collection from other sources, which we investigated individually
Northeast States for Coordinated Air Use Management (NESCAUM): CAMNET	15-minute	n/a	only one unique site with short record
Northeast Regional Climate Center (NRCC): CLimate Information for Management and Operational Decisions (CLIMOD)	1-day	n/a	data are duplicate of NCDC
Rhode Island Department of Environmental Management, Office of Water Resources	1-hour	1	record is too short for use in analysis
U.S. Army Corps of Engineers	1-hour	n/a	no suitable dataset available
U.S. Geological Survey (USGS) Connecticut Water Science Center	15-minute	n/a	downloaded but only three years of data available
Vermont Department of Transportation	n/a	n/a	data not suitable for precipitation frequency analysis

Table 2 shows the number of stations formatted and the number of stations retained in the database after implementing station screening and quality control tasks finished so far (described in Sections 1.1.3 and 1.1.4) for three base durations: 1-day, 1-hour, and 15-minute. For stations recording at variable intervals, data were formatted to all three base durations. After screening and quality control tasks, stations are used to compile annual maximum series for all selected durations between a base duration and 60-day (see Section 1.1.2). Figure 3 shows the locations of currently retained 1-day stations and Figure 4 shows locations of 1-hour and 15-minute stations.

Table 2. The number of stations that have been formatted and retained for the analysis per duration.

Base duration	Number of stations formatted	Number of stations after screening
1-day	8,296	5,976
1-hour	1,535	832
15-minute	440	389

Lastly, we are reviewing data to ensure that historically documented extreme events are properly included in our dataset. For example, we are adding the pre-1900 extreme events documented in the *Monthly Weather Review* journals that are not included in the datasets that we collected. In addition, cross-reference of NCDC's statewide 24-hour record rainfall (http://www.ncdc.noaa.gov/extremes/scec/overview) against our data revealed that the NCDC datasets are missing both the Pennsylvania and Rhode Island official state 24-hour precipitation records, despite having official NWS weather gauges at those locations. The Rhode Island 24-hour record precipitation will be manually added to the station in question; the Pennsylvania 24-hour record precipitation is still under investigation.

1.1.2. Annual maximum series extraction

We extracted annual maximum series (AMS) for all of the stations that were retained in the database for durations equal to and longer than the base duration up to 60 days. The criteria for AMS extraction are designed to exclude maxima if there are too many missing or accumulated data during the year and more specifically during critical months when precipitation maxima are most likely to occur ("wet season"). During this recording period, we delineated extreme precipitation climate regions by assessing the periods in which two-thirds of annual maxima occurred at each station for the 1-day and 1-hour durations. These regions are used to assign a wet season for the AMS extraction, analysis of trends in AMS, analysis of temporal distributions, and in portraying the seasonality of annual maxima data. We are in the process of validating the regions.

1.1.3. Station screening

a. Quality control of metadata and location screening

We checked the basic station metadata (latitude, longitude and elevation) and made corrections where appropriate. Specifically, we screened stations that plotted in the ocean or in the wrong state, or had no elevation recorded in the original dataset. Stations that had no elevation were assigned elevations from a 30-second resolution digital elevation model (DEM).

We also checked station locations if their provided elevation was more than 200 feet different than the elevation extracted from the DEM. Such stations were re-located as necessary based on inspection of satellite images, maps and records of the station's history. Misplacement was typically the result of latitude and longitude resolving location to the nearest minute rather than a finer resolution. We will provide original and revised coordinates for all stations used in the analysis in the final NOAA Atlas 14 documentation for the project.

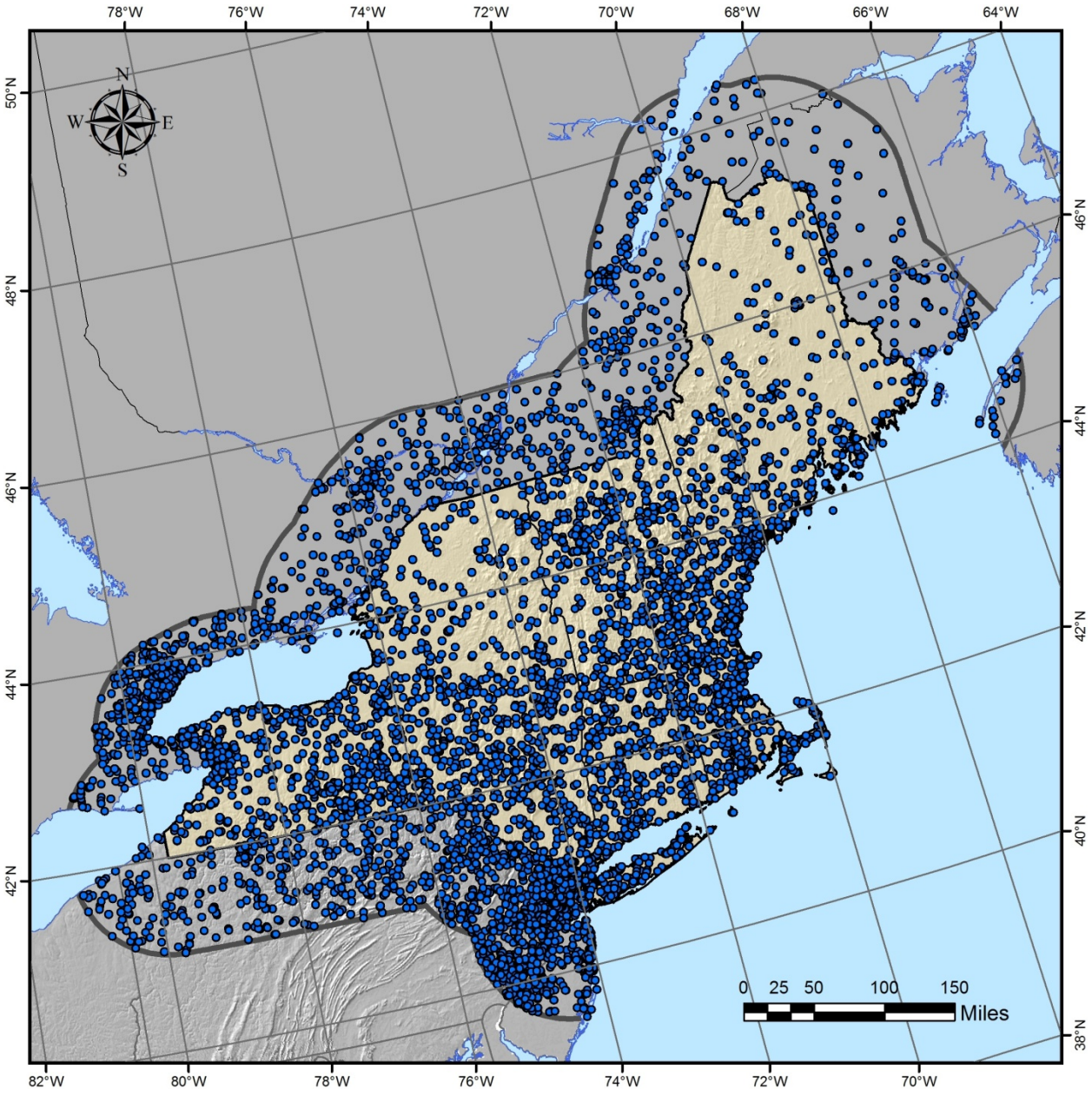

Figure 3. Map of stations whose data were formatted at 1-day interval.

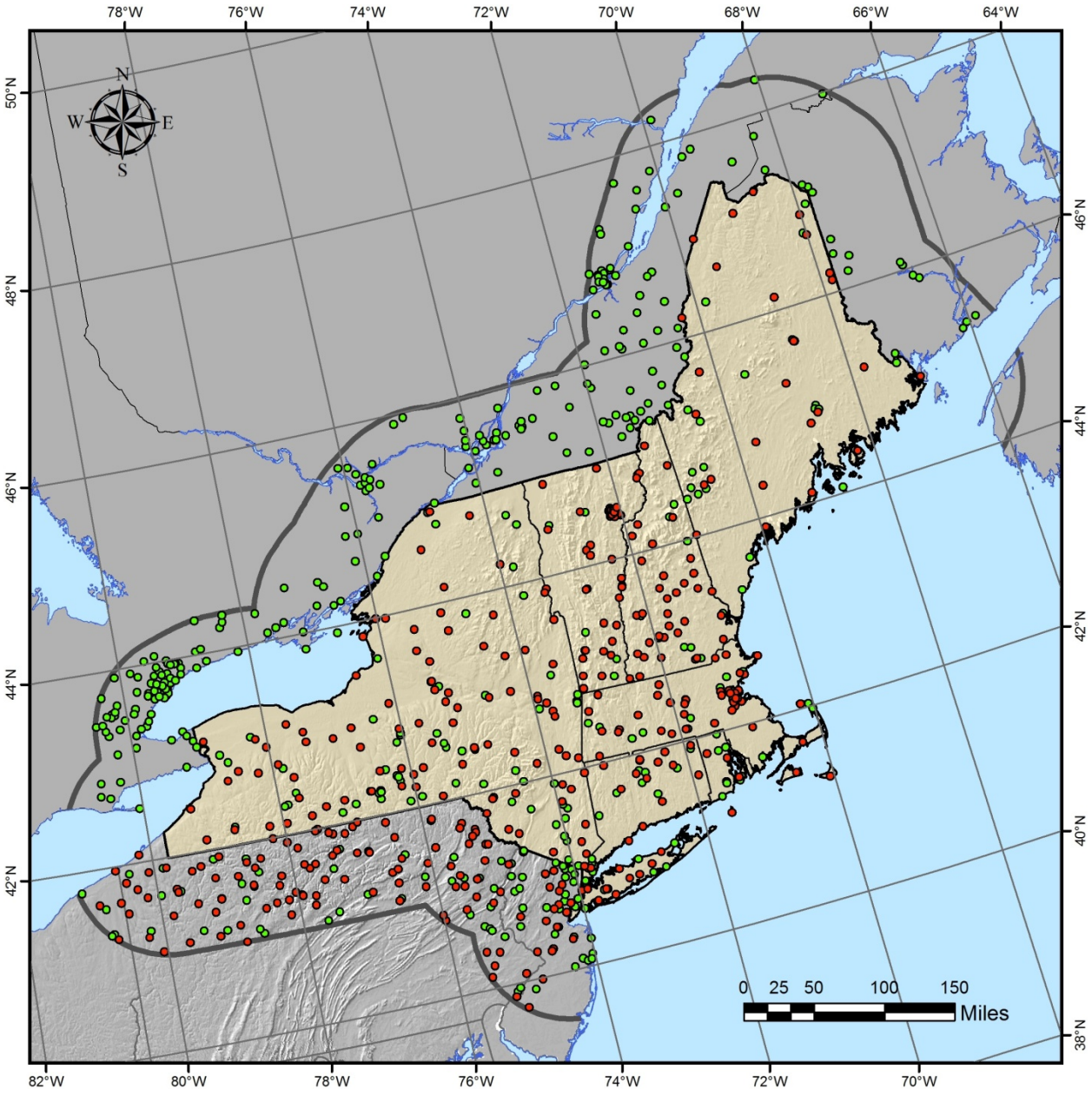

Figure 4. Map of stations whose data were formatted at 1-hour (green circles) and at 15-minute (red circles) intervals.

b. Co-located station cleanup

During this reporting period, we completed additional co-located station cleanup. Co-located stations are defined here as stations that have the same, or very nearly the same, geospatial data, but report precipitation amounts at different time intervals (15-minute, 1-hour, or 1-day). Time series plots of the 1-hour and 1-day annual maximum series of co-located stations were reviewed, where 15-minute and 1-hour data were first aggregated to corresponding durations. If the station with a shorter reporting interval provided the same information as a longer reporting interval, then the station with the longer reporting interval was removed. If the station with the longer reporting interval had 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, stations were extended using data from the shorter reporting interval. The consistency between the 1-hour and 1-day data reported at different time intervals was also inspected. Any disparate maxima were checked for errors. Questionable values were investigated using climatological observation forms, monthly storm data reports and other historical weather event publications and corrected as necessary. As a result of this analysis, we removed 155 stations and extended data at 93 hourly and daily stations.

c. Nearby station cleanup and merges

Nearby stations are defined here as stations within five miles of each other with consideration of elevation differences. We evaluated all daily, hourly and 15-minute nearby stations and considered merging records to increase record lengths. The nearby station cleanup and merge effort for the 15-minute and hourly stations is complete. The cleanup work for daily stations is in progress with 5,216 potential pairs considered for merging. So far, 125 station pairs have been merged and 391 stations have been deleted.

1.1.4. Quality control and data reliability tests

High and low outliers were identified in the distribution of the at-station precipitation AMS. All identified outliers and any other questionable maxima are now being verified, corrected, or removed from the dataset. Statistical tests for outliers are used to identify low and high outliers for all extracted durations (see an example of outlier examination in Figure 5). All values identified as high outliers are mapped with concurrent measurements at nearby stations. Questionable values that cannot be confirmed by measurements at nearby stations are advanced for further investigation. Detailed investigation of flagged amounts is based on climatological observation forms, monthly storm data reports and other historical weather events publications, obtained primarily from the NCDC's Environmental Document Access and Display System (EDADS).

The quality control of AMS for three base durations, 1-day, 1-hour, and 15-minute, are considered first. The quality control task for 15-min data is completed. The 1-day and 1-hour quality control tasks are in progress.

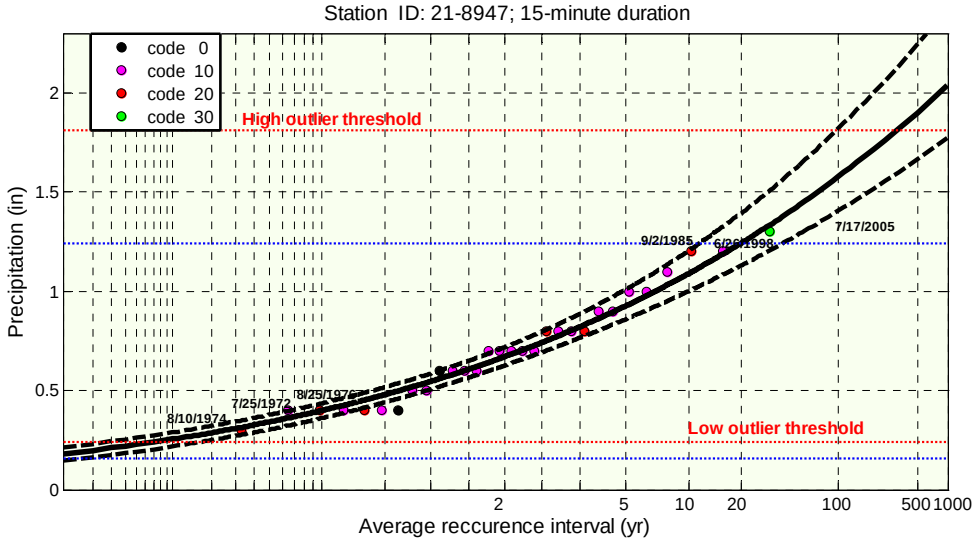

Figure 5. Outlier examination of 15-min AMS at station 21-8947. Data quality codes were assigned to all annual maxima during the extraction process.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2014)

We will format any additional data acquired in the next reporting period and perform station cleanup and quality control. We will finish all station screening tasks, including checking metadata quality, screening for duplicate stations from different datasets, screening nearby stations for potential merges, and removing any stations not meeting the minimum requirement for data years. We will finish work on quality control of high and low outliers in the annual maximum series for all base durations and complete all data reliability tests. We will start an analysis of mean annual maxima (MAM) at base durations.

1.3. PROJECT SCHEDULE

Data collection, formatting, and initial quality control [Complete]

Extraction of annual maximum series (AMS); additional quality control and data reliability tests (e.g., outliers, trend analysis, independence, consistency across durations, duplicate stations, candidates for merging) [January 2014]

Regionalization and frequency analysis [July 2014]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [December 2014]

Peer review [December 2014]

Revision of PF estimates [June 2015]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [July 2015]

Web publication [September 2015]

2. AREAL REDUCTION FACTORS

2.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2013)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same annual exceedance probability for an area of interest. This is a fixed-area definition which is different from the moving storm-based depth-area relationships used with probable maximum precipitation.

HDSC performed an extensive literature review of fixed-area ARF methods and their main advantages and disadvantages. Three diverse methods were selected for further evaluation. Selection was done primarily from the perspective of their potential application to NOAA Atlas 14 precipitation frequency estimates. More details on method selection and initial evaluation of selected methods is available in HDSC quarterly progress report for July - September 2013 period.

During this reporting period, we continued testing the sensitivity of two preferred ARF methods to the choice of rainfall data used in the analysis (radar versus interpolated rain gauge data), effects of different interpolation schemes and evaluation of differences in results between two selected methods.

We also obtained a 4-km gridded daily precipitation dataset for the contiguous United States for the period from 1981 to 2010, which was recently developed by the PRISM Climate Group at the Oregon State University (http://www.prism.oregonstate.edu). We are currently working on downscaling this product to hourly durations using approaches similar to downscaling approaches applied in the NWS Distributed Model Intercomparison Project, Phase 2 (http://www.nws.noaa.gov/oh/hrl/dmip/2/wb_precip.html). We also downloaded and formatted the North American Land Data Assimilation System (NLDAS-2) hourly product (http://ldas.gsfc.nasa.gov/nldas/NLDAS2forcing.php), which will be used to assist in downscaling.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2014)

We will continue comparison of results of selected areal reduction factors methods and finish development of downscaling techniques.

2.3. PROJECT SCHEDULE

The expected completion date for this project is September 2014.

3. INVESTIGATING THE POTENTIAL IMPACT OF CLIMATE CHANGE ON PRECIPITATION FREQUENCY ESTIMATES

3.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2013)

The methodology used in developing NOAA Atlas 14 estimates assumes stationarity in the historical data used in making the estimates. Design based on the estimates themselves assume stationarity in the future. There is considerable speculation as to whether these assumptions of stationarity are appropriate. The published literature provides mixed results with authors from different disciplines examining different climatological aspects of precipitation.

The Federal Highway Administration (FHWA) has an interest in better understanding the potential impact of climate change so that designers of future infrastructure will use appropriate design standards. As part of that effort, FHWA tasked HDSC with analyzing trends in historical rainfall exceedances and in specific intensity-duration-frequency precipitation magnitudes from NOAA Atlas 14 and to determine how HDSC findings compare to corresponding results obtained in the climate community.

Bonnin et al. (2012)[1] analyzed trends in historical rainfall exceedances in the observed record. The areas examined were the domains of NOAA Atlas 14, Volume 1 (Semiarid Southwest) and Volume 2 (Ohio River Basin). Their analysis showed that the historical trends in the number of exceedances of precipitation frequency thresholds are small, in many cases statistically insignificant, showing both increases and decreases, and showing no clear relationship in trend between durations. NOAA Atlas 14 Volumes 3-9 have now been published (Figure 1), and HDSC is extending this historical trend analysis to areas of the country that were not included in Bonnin et al. (2012) to determine if the initial results hold in other areas. During this period, we extended this analysis for 6 Southeastern states covered in Volume 9. Analysis was done independently for each climate region delineated for developing the NOAA Atlas 14 estimates. These climate regions are based on climatology of extreme precipitation.

In addition we identified state of the art methods for analyzing trends in precipitation magnitudes that we will apply in pilot projects to determine their suitability for use across the whole country.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2014)

We will extend the work on analysis of trends in rainfall exceedances to areas of the country covered in remaining NOAA Atlas 14 volumes. We'll also finish development of techniques for examining and expressing trends in precipitation magnitudes. We will start looking at the impact on the estimates of incorporating non-stationarity in distribution parameters relative to change of the method of estimation under stationary conditions.

3.3. PROJECT SCHEDULE

Expected completion date for this pilot project is December 2014.

[1] Bonnin, Geoffrey M., Kazungu Maitaria. and Michael Yekta, 2011. "Trends in Rainfall Exceedances·in the Observed Record in Selected Areas of the United States". Journal of the American Water Resources Association (JAWRA) 46(2): 344-353. DOl: 1 0.1111/j.1752-1688.20 ll.00603.x

III. OTHER

1. RECENT MEETINGS AND CONFERENCES

- On November 5th, Dr. Sanja Perica gave a webinar on the techniques used in preparing the recently published precipitation frequency estimates for southeastern states. The presentation was made to the Florida Department of Transportation and Florida Water Management Districts.
- On October 31st and on December 16th, Ms. Sandra Pavlovic gave a webinar on NOAA Atlas 14 products and methods to the Silver Jackets. Silver Jackets brings together state, federal, and sometimes tribal and local agencies to learn from one.
- On December 3rd, HDSC hosted a group of 28 undergraduate students from the Civil Engineering Department of George Washington University. Dr. Perica gave a presentation on NOAA/NWS organization and history, and role of HDSC group in engineering design.
- Ms. Pavlovic attended the American Geophysical Union (AGU) Fall Meeting in San Francisco where she gave a presentation on NOAA Atlas 14 products and methods on December 13th.

2. GOVERNMENT SHUTDOWN

The Federal Government shutdown, which lasted for two weeks from October 1st to October 17th, impacted our work progress. The Precipitation Frequency Data Server, which is used to disseminate precipitation frequency estimates and related information, was also unavailable during that period.

3. PERSONNEL

Debbie Martin, a long-time contractor with HDSC, departed on October 31st for a new career opportunity. Many of you have interacted with Debbie. She will be missed.