HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 January 2014 to 31 March 2014

Office of Hydrologic Development

National Weather Service

National Oceanic and Atmospheric Administration

U.S, Department of Commerce

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DISCLAIMER

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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.

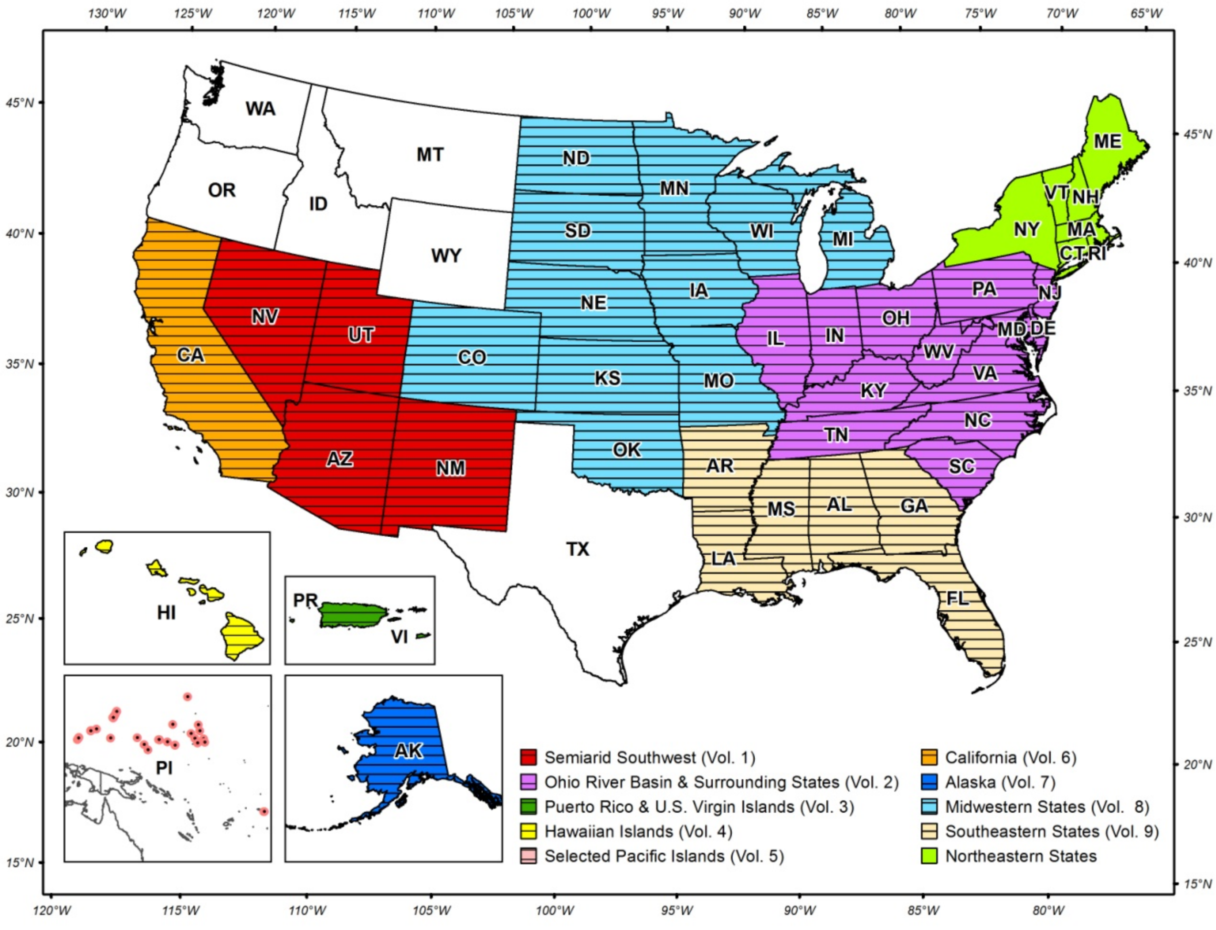

Figure 1. Current project area and project areas included in published NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2014)

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).

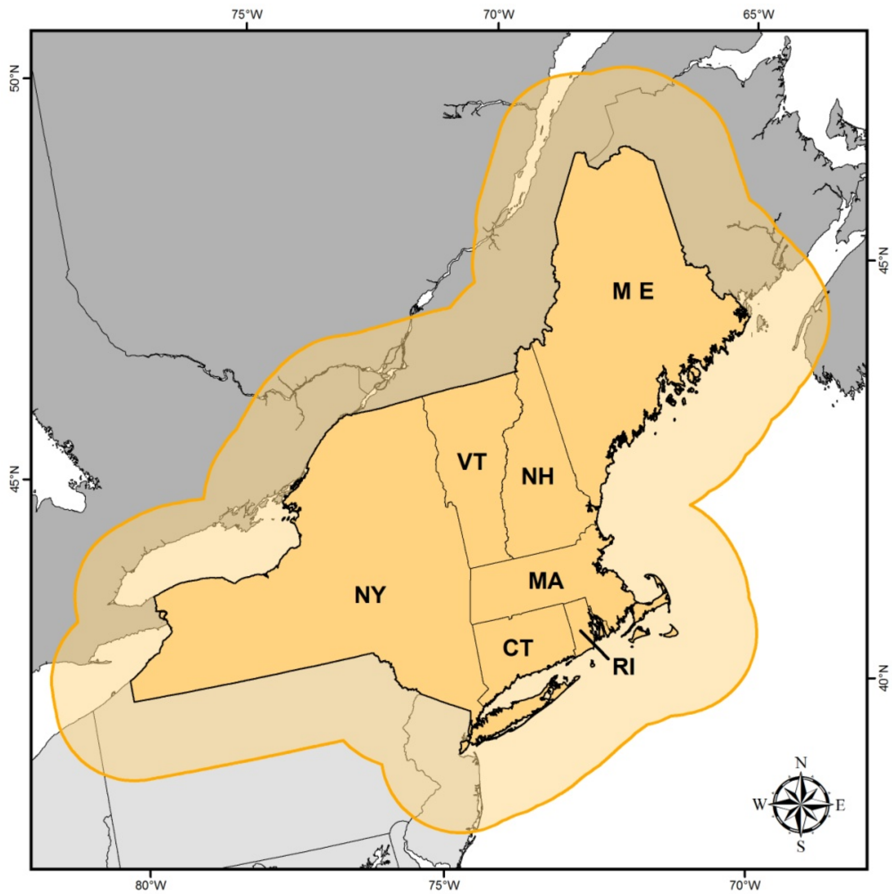

Figure 2. Northeastern precipitation frequency project area (shown in orange).

During this reporting period, we mostly completed work on data collection and formatting, station screening and annual maximum series quality control tasks, and started analysis of at-station mean annual maxima. However, we are still trying to obtain more data for the areas of low station density, such as Maine. **If you know about any dataset in addition to those listed in Table 1 below, particularly in areas that do not have good coverage (see Figure 3 and 4 below for spatial distribution of stations 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:

- formatted data from the Earth Networks dataset;
- collected and formatted data obtained from the New York City Department of Environmental Protection (NYCDEP).

Table 1 lists all datasets collected so far. Datasets which were investigated, but will not be retained for the precipitation frequency analysis are also listed at the bottom of the table. Those datasets typically contained stations which were already included in other datasets or none of the stations in the database had a record length that was sufficiently long and could not be merged with any nearby station to increase its record length (see Section 1.1.2).

Table 1. List of collected datasets. The last ten rows (shaded in gray) list agencies that were contacted, but their datasets will not be used for reasons listed below.

Source of data: dataset	Reporting interval	Number of stations in the dataset	Comments
Automated Surface Observing Systems (ASOS)	1-minute	42	
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)	1-day	2,637	many stations only have a few years of data
Boston Water and Sewer Commission	15-minute 1-hour	6 6	
Earth Networks	variable	1,324	many stations only have a few years of data
Environment Canada	1-day 1-hour	2,980 536	
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	1-day	62	
Massachusetts Department of Conservation and Recreation (DCR)	1-day	176	digitized data only for relevant stations
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	variable	336	
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	1-day	63	
Mount Washington Observatory	1-hour 1-day	1 1	sent inquiries; waiting for data
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	
NCDC: U.S. Climate Reference Network (USCRN)	1-day 1-hour	11 11	
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	1-day	1	
New Hampshire Department of Transportation	15-minute	15	
Office of the New Jersey State Climatologist at Rutgers University: NJ Mesonet	variable	7	

Source of data: dataset	Reporting interval	Number of stations in the dataset	Comments
Office of the New Jersey State Climatologist at Rutgers University: NJ SafetyNet	variable	5	
U.S. Department of Agriculture: Agricultural Research Service (ARS)	variable	23	metadata digitized from paper maps
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	1-hour	40	
USGS Maine Water Science Center	1-day 15-minute	16 0	
USGS Massachusetts-Rhode Island Water Science Center	1-day 1-hour 15-minute	5 1 16	
USGS New Hampshire-Vermont Water Science Center	1-day 15-minute	6 0	
USGS New York Water Science Center	1-day	1	
York City Department of Environmental Protection (NYCDEP)	1-hour 1-day	25 7	
Citizen Weather Observers Program	1-hour	n/a	short records
Connecticut ALERT Network: Automated Flood Warning Systems (AFWS)	variable	n/a	network discontinued; no suitable archived dataset available
Cornell University: Network for Environment and Weather Applications (NEWA)	1-hour	n/a	short records
NCDC: Global Summary of the Day	1-day	n/a	duplicate of NCDC and Environment Canada data
NOAA Earth Systems Research Laboratory, Meteorological Assimilation Data Ingest System (MADIS)	various	n/a	collection of stations from other sources already in dataset
Northeast States for Coordinated Air Use Management: CAMNET	15-minute	n/a	only one unique station with short record
Northeast Regional Climate Center: CLimate Information for Management and Operational Decisions (CLIMOD)	1-day	n/a	duplicate of NCDC data
Rhode Island Department of Environmental Management, Office of Water Resources	1-hour	n/a	short records
U.S. Army Corps of Engineers offices in Baltimore, Buffalo, New York, Philadelphia, Pittsburg	1-hour	n/a	no suitable dataset available
U.S. Geological Survey (USGS) Connecticut Water Science Center	15-minute	n/a	short records

Table 2 shows the number of stations formatted and the number of stations retained for frequency analysis (see Section 1.1.2 for more details) 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. Figures 3 and 4 show the locations of currently retained daily and sub-daily stations, respectively.

Table 2. The number of stations that have been formatted and retained for further analysis for three base durations.

Base duration	Number of stations formatted	Number of stations retained
1-day	8,317	1,331
1-hour	3,546	338
15-minute	434	211

1.1.2. Station screening

a. Quality control of station metadata

For newly collected stations, we screened station metadata (latitude, longitude and elevation) and made corrections where appropriate. For example, if the provided elevation was more than 200 feet different than the elevation extracted from a one arc-second resolution digital elevation model (DEM), the station was re-located as necessary 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. The original and revised coordinates for all stations used in the analysis will be provided in Appendix 1 of the accompanying NOAA Atlas 14 Volume 10 document. Stations with no elevation information were assigned DEM elevations.

b. Merging records at nearby stations

The records of nearby stations were considered for merging to increase record lengths. Nearby stations were defined as stations located within five miles of each other, with elevation differences taken into consideration. Of the 5,216 pairs of stations that were investigated in this task, 985 have been merged.

c. Record length

Record length was characterized by the number of years for which annual maxima could be extracted (i.e., data years) rather than the entire period of record (see Section 1.1.3 for more information). Generally, only stations with at least 30 data years are considered for frequency analysis. Allowances were made for isolated stations or stations recording at very short intervals. A minimum of 20 data years was used to pre-screen hourly and 15-minute stations.

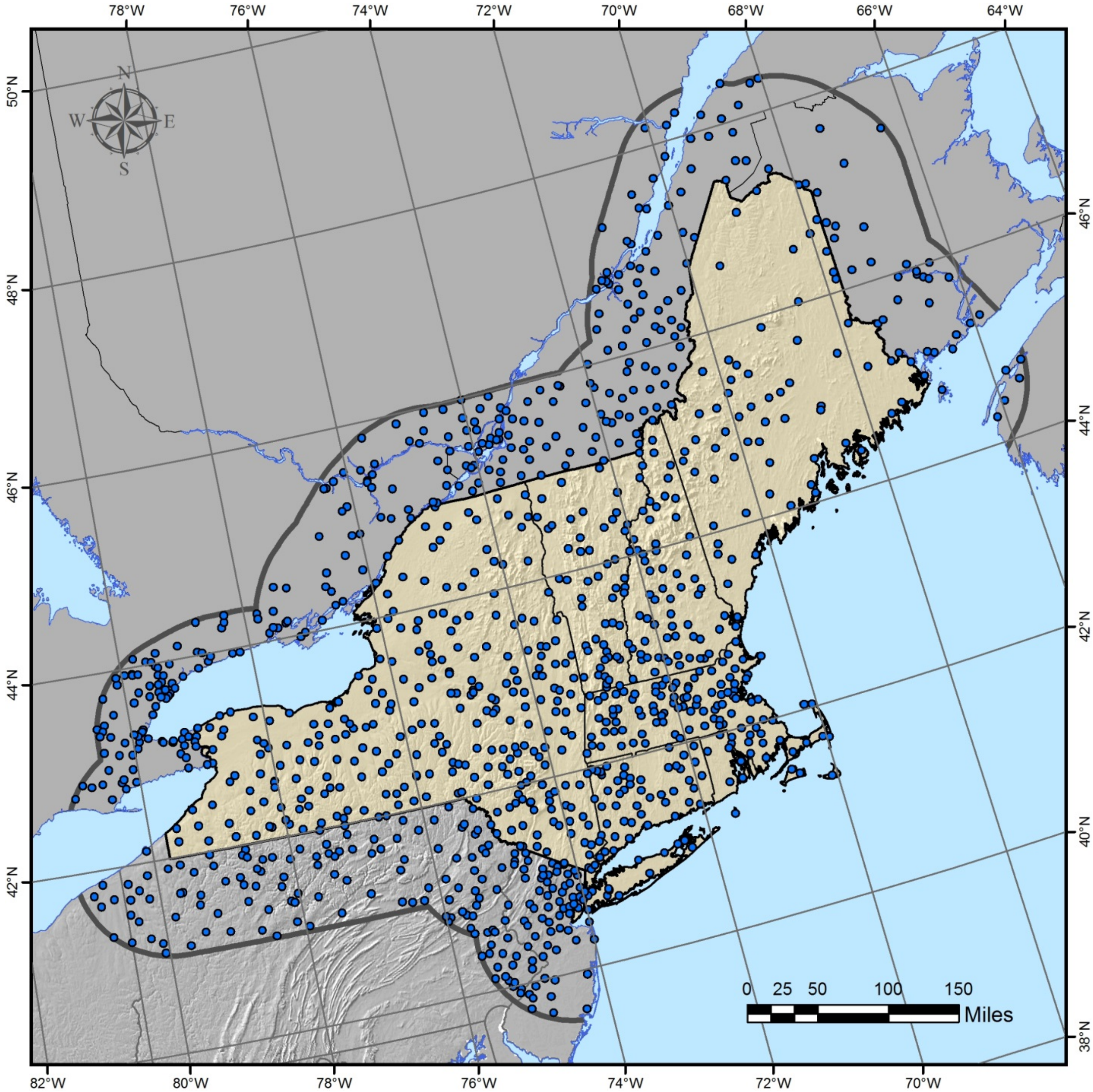

Figure 3. Map of daily stations retained in the dataset.

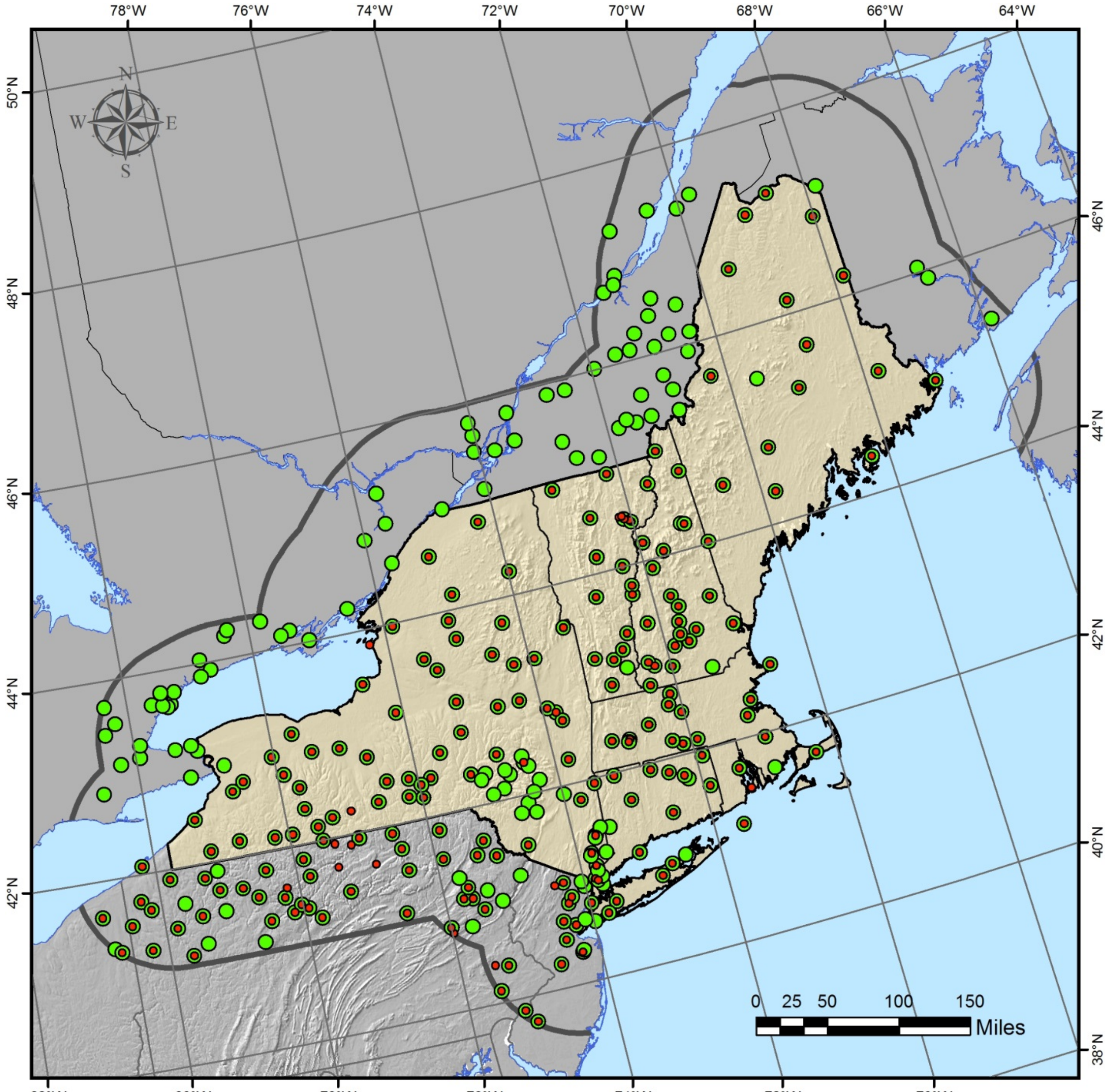

Figure 4. Map of hourly (green circles) and 15-minute (red circles) stations retained for further analysis.

1.1.3. Annual maximum series extraction and delineation of climate regions

The precipitation frequency analysis approach used in this project is based on analysis of annual maximum series (AMS) across a range of durations from 5 minutes to 60 days. AMS for each station were obtained by extracting the highest precipitation amount for a particular duration in each successive year. AMS at stations were extracted for all 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 during critical months when precipitation maxima are most likely to occur (wet season) in their assigned climate region. Two climate regions, as shown in Figure 5, were delineated through assessment of the periods in which two-thirds of annual maxima occurred at each station and by inspecting histograms of annual maxima for the 1-day and 1-hour durations in corresponding climate regions. In addition to the AMS extraction task, these climate regions will be used in the analysis of trends in AMS, analysis of temporal distributions, and in portraying the seasonality of annual maxima.

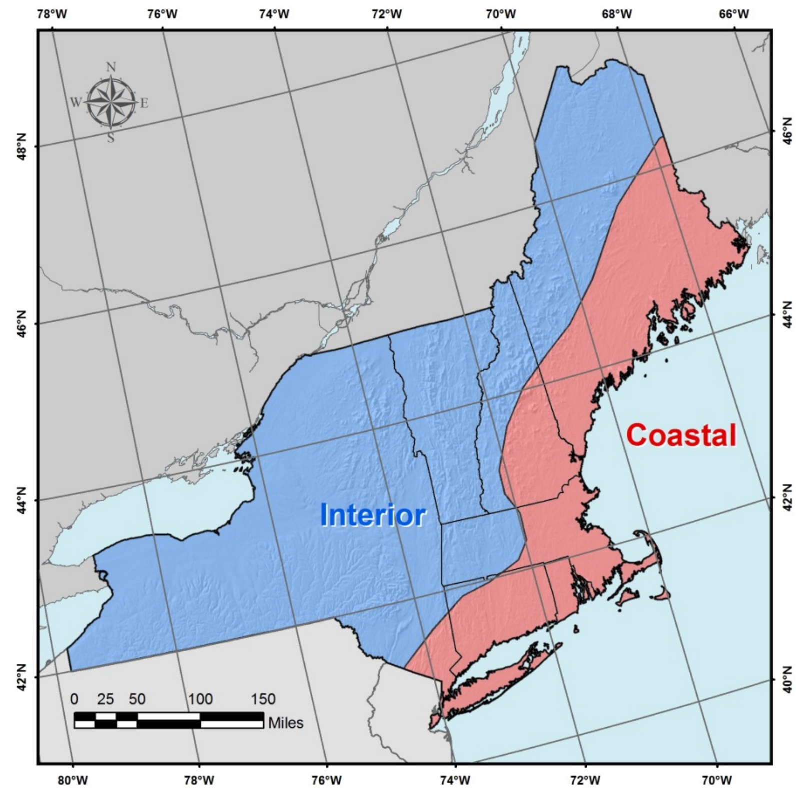

Figure 5. Delineated climate regions.

1.1.4. AMS quality control

In NOAA Atlas 14, outliers are defined as annual maxima which depart significantly from the trend of the corresponding remaining maxima. Since 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. Statistical tests for outliers are used to identify low and high outliers for all extracted durations (Figure 6). 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 Images and Publications System (IPS).

The quality control was first done for AMS at three base durations (1-day, 1-hour, and 15-minute). The quality control of 15-min and 1-hour AMS data is complete. Quality control is near completion for the 1-day duration.

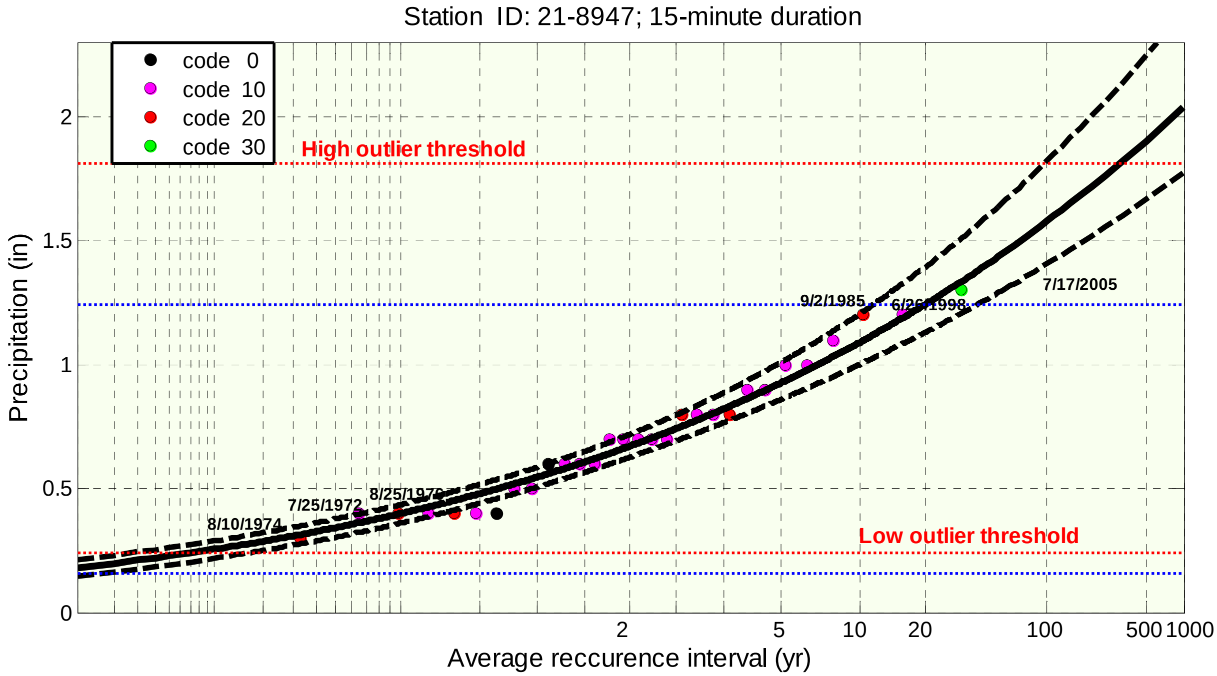

Figure 6. Outlier examination of 15-min AMS at station 21-8947. Data quality codes, which indicate amount of missing data or accumulations in the record, were assigned to all annual maxima during the extraction process.

1.1.5. Mean annual maxima analysis

We started spatial analysis of at-station mean annual maximum (MAM) estimates for 1-hour, 1-day and 10-day durations. During this analysis, MAM data for each station is reviewed relative to MAMs at nearby stations. The goal is to identify locations where MAMs are affected by short periods of record or missed heavy events, before estimates are spatially interpolated. MAM grids are the basis for the derivation of gridded precipitation frequency estimates.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - June 2014)

In the next reporting period, we'll send at-station MAMs for 15-minute, 1-hour, 1-day and 10-day to Oregon State University's PRISM Climate Group for high-resolution spatial interpolation using their hybrid statistical-geographical approach for mapping climate data. This task typically requires several iterations. We'll use MAM grids to further examine at-station MAM data. Based on that review, we'll make adjustments of at-station MAM data and send data back to PRISM for interpolation, as necessary. Also, we'll complete AMS trend analysis and consistency analysis of AMS data across durations and start at-station frequency analysis.

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) [Near completion]

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 PROJECT

2.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2014)

Areal reduction factors (ARF) are needed to transform average point precipitation frequency estimates for an area of interest to corresponding areal estimates that have the same probability of exceedance. Among the different ARF derivation methods, the "geographically-fixed" method is the established method for use with precipitation frequency studies.

As already reported, based on an extensive review of geographically-fixed ARF derivation methods, two quite different methods were selected for further evaluation. Methods were selected 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 are available in HDSC quarterly progress report for July - September 2013 period.

A major difficulty for ARF-related activities is the lack of good quality, high-resolution hourly precipitation data. Historically, ARF relationships were developed on the basis of spatially interpolated rain gauge data, and therefore were susceptible to selection of interpolation method and spatial density. With the ongoing availability of radar rainfall records, multi-sensor (radar + rain gauge) gridded precipitation estimates, such as the national Stage IV hourly product on the HRAP (~ 4km) grid, are becoming more relevant. The short temporal records of the multi-sensor datasets is a limiting factor for statistical analysis. For example, Stage IV data are available only from January 2002 (~12 years of data), compared to approximately 60 years for many hourly gauges and over 100 years for daily gauges.

The PRISM Climate Group at Oregon State University recently released a gridded, daily precipitation product for the contiguous United States at 150 arc-second (~ 4 km) resolution for the 1981 - present period (http://www.prism.oregonstate.edu/recent/). During this reporting period we downscaled daily data from this dataset to hourly durations using the North American Land Data Assimilation System (NLDAS-2) product. The NLDAS-2 precipitation data are available at hourly time steps in 1/8th-degree (~12 km) resolution, with period of record ranging from January 1979 to present. We used ratios of hourly and daily NLDAS-2 grids to downscale PRISM daily grids to hourly durations; an assumption was made that ratios were constant for all PRISM grids inside a single NLDAS-2 grid.

During this reporting period, we continued testing the sensitivity of the two preferred ARF derivation methods to the choice of rainfall data used in the analysis. We compared resulting ARFs from: a) Stage IV product; b) daily PRISM product; c) hourly product that is a composite of PRISM and NLDAS-2 data. We also started an assessment of the variability of ARFs on average recurrence intervals. Some preliminary results of these analyses will be reported in the next quarterly progress report.

Due to the significance of the ARF products for several federal agencies, we plan to conduct an independent peer review by these agencies' experts in the near future for this project. We will also be seeking review by other stakeholders.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - June 2014)

We will continue testing the sensitivity of the two preferred areal reduction factor derivation methods to the choice of rainfall data and analyze the dependence of ARFs on different annual exceedance probabilities. We'll also apply the ARF derivation methods in a couple of different areas to investigate differences in ARFs for different climate regimes.

Preparation for the review process will start during this reporting period.

2.3. PROJECT SCHEDULE

Due to anticipated peer review, the completion date of this project has to be postponed. Our new estimate for the project completion is June 2015.

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

3.1. PROGRESS IN THIS REPORTING PERIOD (Jan - Mar 2014)

The methodology used in developing NOAA Atlas 14 estimates assumes stationarity in the historical data used in making the estimates. Designs based on the estimates themselves assume stationarity in the future. There is considerable speculation as to whether these assumptions 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 on precipitation frequency estimates 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, specifically with intensity-duration-frequency precipitation magnitudes from NOAA Atlas 14 and to determine how HDSC findings compare to corresponding results obtained in the climate community.

3.1.1. Analysis of trends in historical rainfall exceedances

Bonnin et al. (2011)[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 and Surrounding States). 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.

We are extending this analysis to all states in the contiguous USA for which we have NOAA Atlas 14 coverage to determine if the initial results hold in other areas. During this period, we completed this analysis for states in the domain of NOAA Atlas Volumes 6, 7, 8 and 9. Analysis was done separately for each climate region delineated in various NOAA Atlas 14 volumes. These climate regions were developed based on analysis of the climatology of extreme precipitation; more details are available from NOAA Atlas 14 documents.

3.1.2. Modeling precipitation frequency estimates under non-stationary conditions

Precipitation magnitude-frequency relationships in NOAA Atlas 14 Volumes have been computed using a regional frequency analysis approach on the AMS data based on L-moment statistics, where typically the 3-parameter (location, scale and shape) Generalized Extreme Value (GEV) distribution was the distribution of choice. Since the current approach is not suitable for frequency analysis in the presence of non-stationarity, we have been examining the Maximum Likelihood approach for estimation of GEV distribution parameters. We are pursuing a flexible modeling framework for non-stationary generalized extreme value analysis of AMS, in which relationships between distribution parameters and time could be also non-linear. During this reporting period, most of the effort went on development of this framework.

[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

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Apr - June 2014)

We will finish development of a non-stationary GEV model and start looking at the impact of incorporating non-stationarity on precipitation frequency estimates.

3.3. PROJECT SCHEDULE

Expected completion date for this pilot project is December 2014.

III. OTHER

1. RECENT MEETINGS AND CONFERENCES

On March 12, Sandra Pavlovic, a UCAR employee supporting HDSC, gave an invited, web-based presentation on NOAA Atlas 14 to faculty, staff, and students of the Iowa Flood Center at the University of Iowa.

On March 13 and 14, Geoff Bonnin and Sandra Pavlovic participated (by invitation of the Nuclear Regulatory Commission (NRC)) in a Bilateral Technical Exchange Workshop between the French Institut de Radioprotection et Surete Nucleaire (IRSN), the French Autorite De Surete Nucleaire (ASN) and NRC, on Probabilistic Flood Hazard Assessment and Flood Protection. Geoff made a presentation on NOAA Atlas 14 and probabilistic flood hazard assessment. The French nuclear regulatory agencies have similar interests in relation to protection of their nuclear facilities. We were able to discuss approaches to estimating precipitation (and flood) frequency, in the frequency range of NOAA Atlas 14 and beyond towards probable maximum precipitation.

2. PERSONNEL

Geoff Bonnin, Chief of the Hydrologic Science and Modeling Branch of the NWS Office of Hydrologic Development, has announced he will retire from the Federal Government at the end of May. We have had the privilege of working with Geoff on critically important precipitation frequency atlases that will be used for decades and have economic impacts on the order of billions of dollars. He played a key role in the development of NOAA Atlas 14 and the activities of HDSC and so his departure will be a big loss for us. We would like to thank him for his invaluable contribution and we wish him the best in his retirement. We will miss him, as will many of you who have worked with him over many years.