HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 April 2014 to 30 June 2014

Office of Hydrologic Development
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 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.

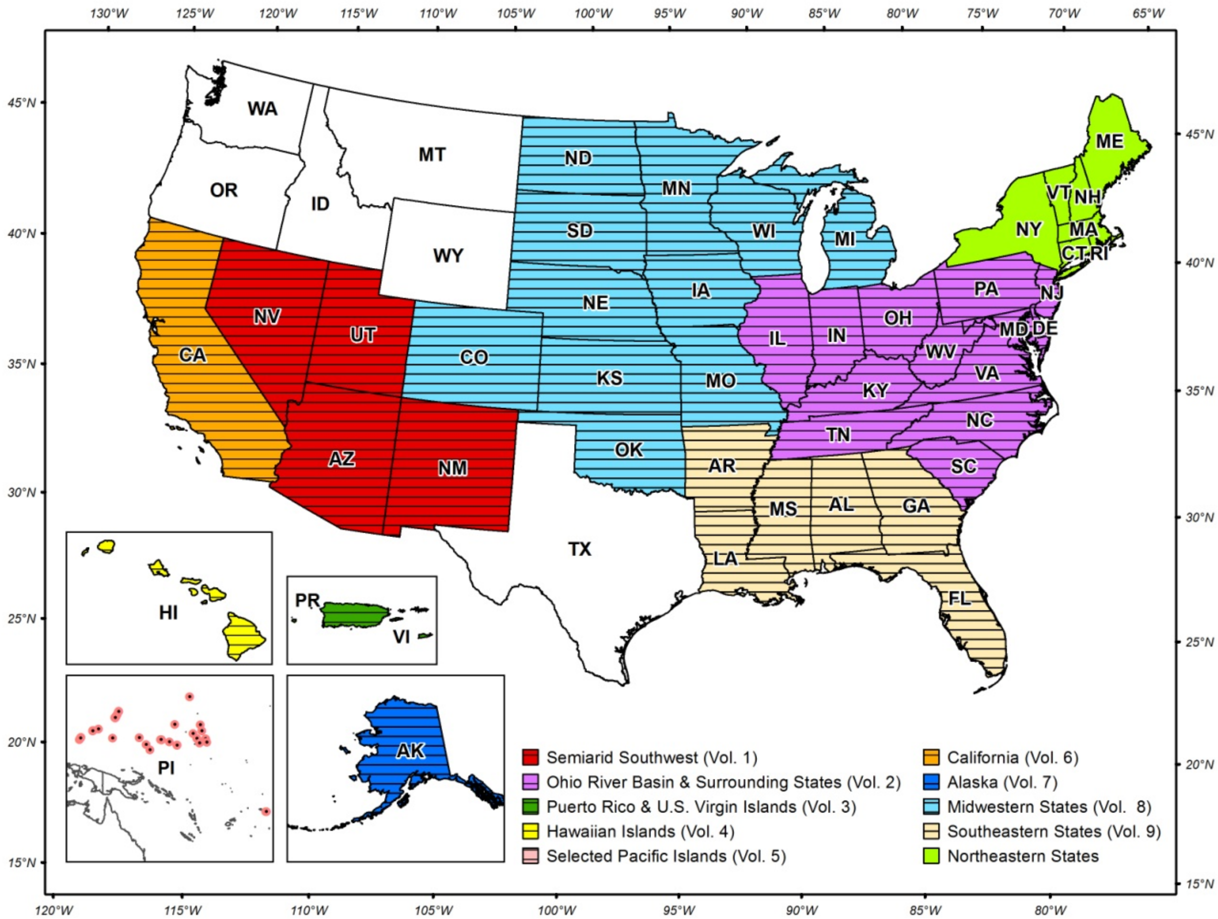

Figure 1. Current project area and project areas included in published NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Apr - Jun 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).

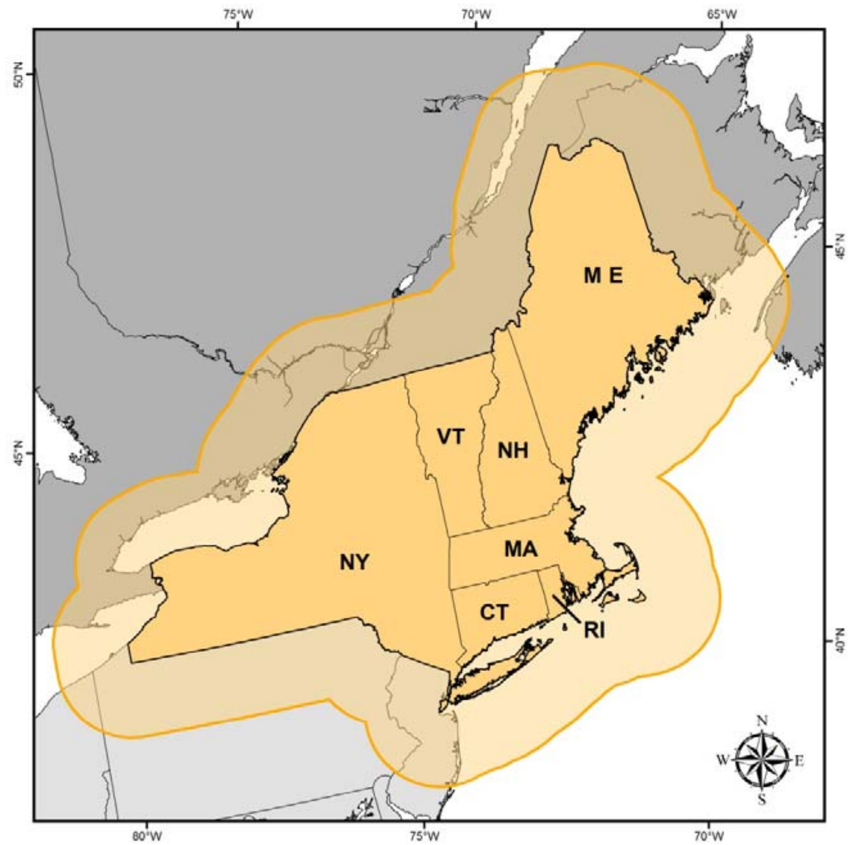

Figure 2. Northeastern precipitation frequency project area (shown in orange).

During this reporting period, we mostly completed work on station screening, various quality control tasks and analysis of at-station mean annual maxima. We started the regionalization task. Additional work was also done on data collection and formatting. 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 Figures 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 Eastern New York Observing Network;
- formatted data received from Lyndon State College in Vermont;
- collected and formatted additional Automated Surface Observing Systems (ASOS) and Automated Weather Observing System (AWOS) stations.

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 contain stations which were already included in other datasets or none of the stations in the database has a record length that is sufficiently long to be used by itself 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) and Automated Weather Observing System (AWOS)	1-minute	107	
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	6	
	1-hour	6	
Earth Networks	variable	1,324	many stations only have a few years of data
Environment Canada	1-day	2,980	
	1-hour	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	sent inquiries; waiting for data
	1-day	1	

Source of data: dataset	Reporting interval	Number of stations in the dataset	Comments
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	1-day	3,001	
	1-hour	593	
	15-minute	517	
	n-minute	43	
NCDC: U.S. Climate Reference Network (USCRN)	1-day	11	
	1-hour	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	
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	16	
	15-minute	0	
USGS Massachusetts-Rhode Island Water Science Center	1-day	5	
	1-hour	1	
	15-minute	16	
USGS New Hampshire-Vermont Water Science Center	1-day	6	
	15-minute	0	
Lyndon State College	15-min	1	
Eastern New York Observing Network	1-day	2	
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

Source of data: dataset	Reporting interval	Number of stations in the dataset	Comments
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 currently retained for further 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	8,319	1,159
1-hour	3,546	364
15-minute	503	105

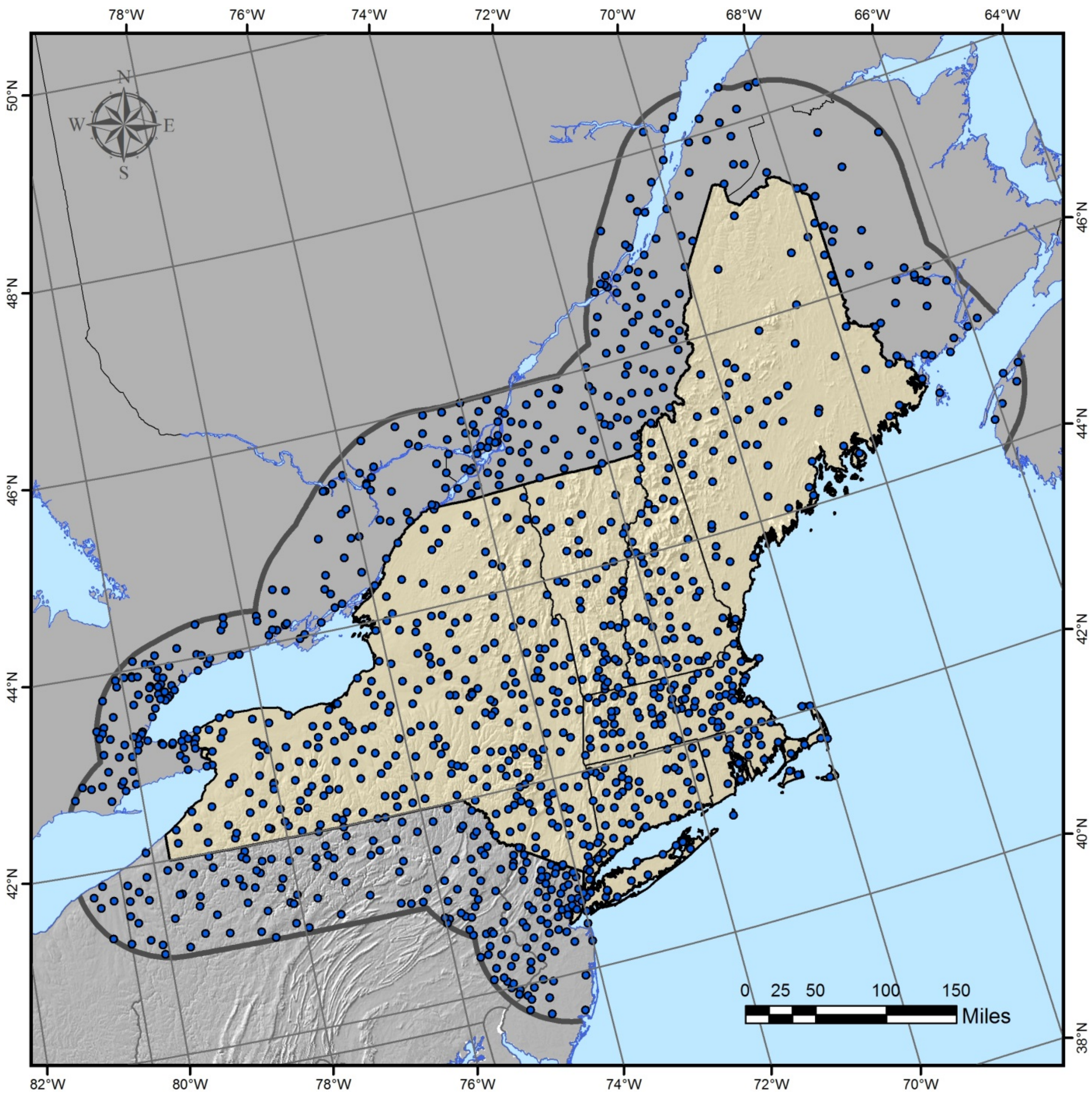

Figure 3. Map of daily stations currently retained in the dataset.

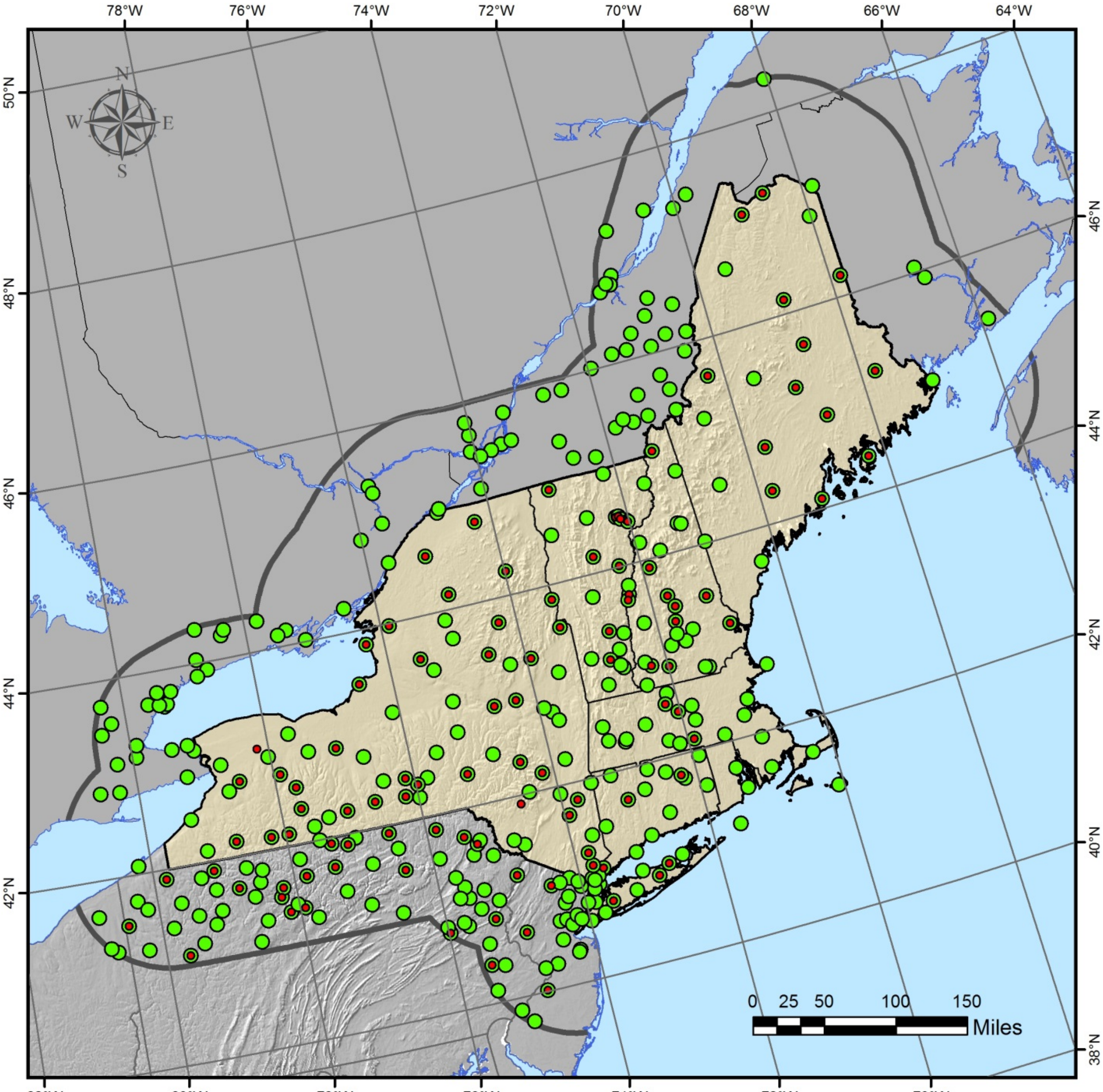

Figure 4. Map of hourly (green circles) and 15-minute (red dots) stations retained for further analysis.

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. 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 stations

The records of nearby stations were considered for merging to increase record lengths. Nearby stations were defined as stations within five miles of each other with elevation differences taken into consideration. Further investigation of possible merges has led to an additional 62 pairs of stations being merged or extended during this reporting period.

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 1.1.4 for more information). Generally, only stations with at least 30 data years (after merging) are considered for frequency analysis for daily durations. Allowances were made for isolated stations, high elevations stations, and stations recording at sub-daily intervals. A minimum of 20 data years was used to pre-screen hourly and 15-minute stations.

1.1.3. Correction for constrained observations

Work began on developing factors to convert constrained observations (e.g., 1-day) to unconstrained values (e.g., 24-hour). Quality-controlled, concurrent constrained and unconstrained annual maxima from hourly stations will be used in a zero-intercept regression model to develop correction factors for daily durations, while co-located hourly (constrained) and n-minute/15-minute (unconstrained) concurrent annual maxima will be used to develop correction factors for 1-hour to 12-hour durations.

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 were used to identify low and high outliers for all durations. All values identified as outliers were mapped with concurrent measurements at nearby stations. Questionable values that could not be confirmed by measurements at nearby stations were advanced for further investigation. Detailed investigation of flagged amounts was 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 of AMS for all durations between 15-min and 60-day has now been completed. Figure 5 shows an example for a longer daily duration, for which statistical tests often identified multiple high outliers.

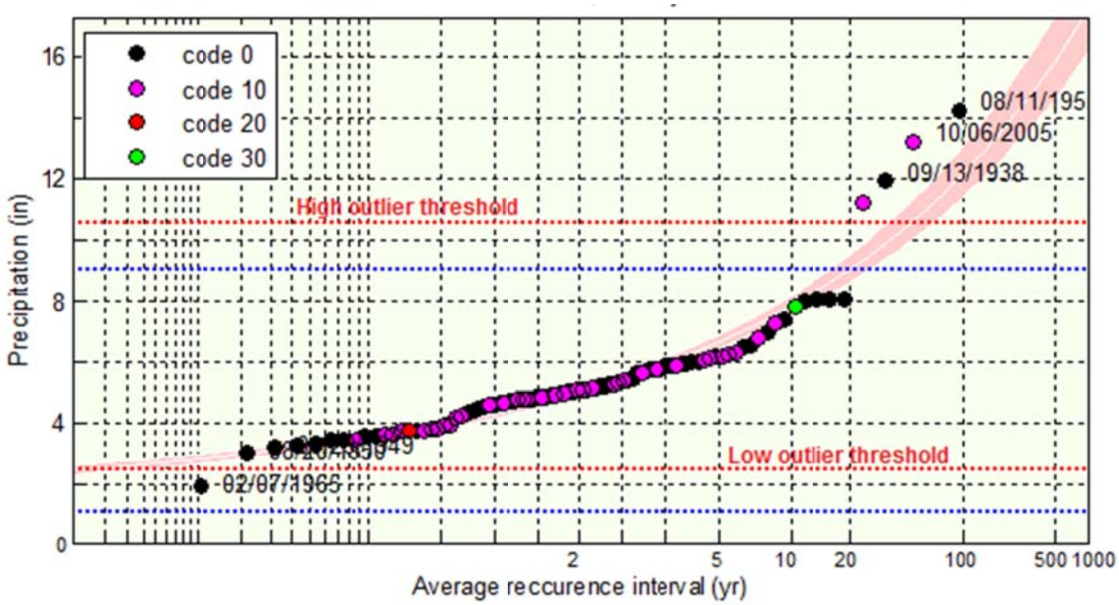

Figure 5. Outlier examination of 10-day AMS at station 30-5377. Data quality codes, which indicate amount of missing data or accumulations in the record, were assigned during the extraction process.

1.1.5. Spatial analysis of mean annual maxima

During the previous reporting period, at-station mean annual maximum (MAM) estimates for durations between 15-min and 60-day were sent to the Oregon State University's PRISM Climate Group for high-resolution spatial interpolation using their hybrid statistical-geographical approach for mapping climate data.

While we are waiting for PRISM products, we continued spatial analysis of at-station MAM estimates for 1-hour, 1-day and 10-day durations. During this analysis, MAM data for each station was reviewed for inconsistencies relative to MAMs at nearby stations. The goal was to identify locations where MAMs were affected by short periods of record or missed extreme amounts. Identified MAMs were investigated and either adjusted or removed from the analysis. This task will require several iterations, before final gridded MAM estimates are developed.

1.1.6. Regionalization

Regional approaches to frequency analysis use data from stations that are expected to have similar frequency distributions to yield more accurate estimates of extreme quantiles than approaches that use only data from a single station. The region of influence approach used in this volume defines regions such that each station has its own region with a potentially unique combination of nearby stations.

During this reporting period, work began on the regionalization task. Initial regions for each station were formed by grouping the closest 10 stations. Each region is then carefully investigated. Stations are added to or removed from regions based on examination of their distance from a target station, elevation difference, inspection of their locations with respect to mountain ridges, and assessment of similarities/dissimilarities in the progression of relevant L-moment statistics across durations compared with other stations in the region. During this process, some inconsistent stations are removed from the analysis, particularly in dense network areas where nearby stations have much longer records.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jul - Sep 2014)

In the next reporting period, the following tasks will be completed: analysis of spatial patterns in mean annual maxima and resolution of any inconsistencies, spatial interpolation of mean annual maxima, regionalization and derivation of depth-duration-frequency curves at gauged locations, and the spatial interpolation of precipitation frequency estimates 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) [Complete]

Regionalization and frequency analysis [Near complete]

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

Peer review [October 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 (Apr - Jun 2014)

Areal reduction factors (ARFs) 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. The first method combines the notion of dynamic scaling with that of statistical self-affinity to find a general functional form for the mean rainfall intensity as a function of both the duration and area. For the second method, point and areal depth-duration-frequency curves are characterized using the Generalized Extreme Value (GEV) distribution, where the distribution parameters are determined as a function of both the area and duration. 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, but 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 many 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/). We used the North American Land Data Assimilation System (NLDAS-2) precipitation data, which are available at hourly time steps in 1/8th-degree (~12 km) resolution, to downscale PRISM daily grids to hourly durations; an assumption was made that ratios of hourly and daily NLDAS-2 data 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) interpolated rain gauge data; b) Stage IV product and c) hourly data that were developed as a composite of PRISM and NLDAS-2 data.

We also looked at the differences in ARFs for different climate regions and effects of average recurrence intervals (ARIs) on the ARF.

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

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jul - Sep 2014)

The NWS headquarters is currently undergoing a total reorganization. The new organizational structure of the NWS headquarters will facilitate more efficient project management. Work on the ARF project will be put on hold while the reorganization is underway. We anticipate that the NWS reorganization will be complete in early FY15.

2.3. PROJECT SCHEDULE

As noted above, the ARF project will be put on hold during the reorganization of the NWS Headquarters.

3. ANALYSIS OF IMPACTS OF CLIMATE CHANGE ON PRECIPITATION FREQUENCY ESTIMATES

3.1. PROGRESS IN THIS REPORTING PERIOD (Apr - Jun 2014)

Precipitation magnitude-frequency relationships in NOAA Atlas 14 Volumes have been computed using a regional frequency analysis approach on the Annual Maximum Series (AMS) data based on L-moment statistics, where typically the 3-parameter Generalized Extreme Value (GEV) distribution was a distribution of choice. This approach assumes stationarity in the AMS data for frequency distribution selection and fitting, and as such, may not be suitable for frequency analysis in the presence of non-stationary climate conditions.

The Federal Highway Administration (FHWA) has an interest in better understanding the potential impact of climate change on the intensity-duration-frequency (IDF) curves at local scales so that designers of future infrastructure will use appropriate design standards. As part of that effort, FHWA tasked HDSC to survey the state of the art methodologies in this area, to conduct a pilot project to analyze trends in historical rainfall exceedances and impacts of climate change on precipitation magnitudes from NOAA Atlas 14 and to determine how HDSC findings compare to corresponding results obtained in the climate community.

For the pilot project, relevant literature has been reviewed, methodologies appropriate for distribution fitting under non-stationary conditions have been identified and related codes have been prepared. A flexible, nonlinear modeling framework for non-stationary GEV analysis developed by Cannon (2010)[1] was selected for further evaluation. In this model, generalized maximum likelihood (MLE) approach is used instead of current NOAA Atlas 14 L-moment approach to calculate GEV parameters, as it allows a time dependency to be introduced in the calculation. Due to the flexibility of its architecture, the model can be used to perform stationary analysis or, when distribution parameters are dependent on time, it can be used to perform non-stationary extreme value analysis. The model is capable of representing a wide range of non-stationary relationships, including those due to inter-decadal climatic variability.

The evaluation of IDFs from various types of non-stationary models against the current NOAA Atlas 14 stationary model has begun. A range of non-stationary models, from the simplest one with a single distribution parameter linearly varying with time to complex models with different types of non-linear trends in all distribution parameters is under investigation.

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[1]A. J. Cannon, 2010. A flexible nonlinear modelling framework for nonstationary generalized extreme value analysis in hydroclimatology. *Hydrological Processes*, 24, 673-685. DOI: 10.1002/hyp.7506.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jul - Sep 2014)

Evaluation of IDFs from various types of non-stationary models against the current NOAA Atlas 14 stationary model will continue.

Partial duration series (PDS)-based frequency analysis approach will also be investigated as an alternative to AMS approach to allow us to investigate potential trends in the frequency of extreme precipitation amounts. One limitation of AMS-based frequency analysis is that only the highest precipitation amount for a given duration for a year is included in the analysis. This means that other significant events from the same year, although potentially larger than the highest rainfall events of other years, are not considered. Consequently, any changes in frequency of extreme events cannot be detected when the analysis is based on the AMS.

3.3. PROJECT SCHEDULE

Expected completion date for this pilot project is December 2014.

III. OTHER

1. STORM ANALYSIS

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events that typically have observed amounts with AEPs of less than 0.2% over extended areas. The maps are available for download from the following page: http://www.nws.noaa.gov/oh/hdsc/aep_storm_analysis/.

For each selected storm event, we look at a range of durations and create a map for the one that shows the lowest AEPs for the largest area. In each analysis, the beginning of the time period for selected duration is not necessarily the same for all locations; as a result, maps do not represent isohyets at any particular point in time, but rather isolines of AEPs within the whole event. The underlying data for these analyses are rainfall observations (usually from Stage IV gridded data) and point rainfall frequency estimates (usually from NOAA Atlas 14).

During this reporting period, HDSC developed a map showing the AEPs of the worst 6-hour rainfall from the 29 - 30 April 2014 event near Pensacola, Florida (Figure 6).

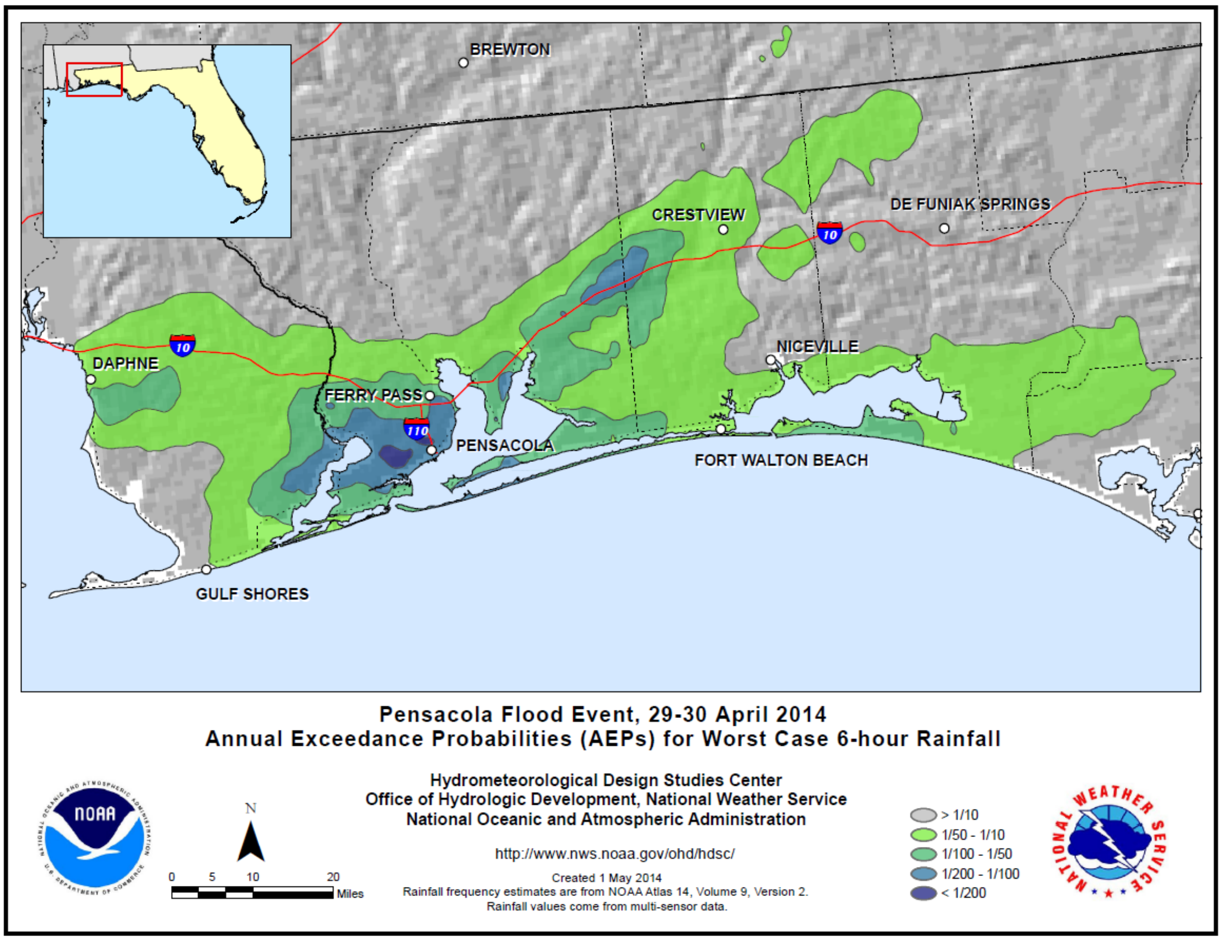

Figure 6. Annual exceedance probabilities for the worst case 6-hour rainfall for the 29 - 30 April 2014 event near Pensacola, Florida.

2. RECENT MEETINGS AND CONFERENCES

HDSC member, Michael St. Laurent, gave a poster presentation “Using radar and gauge data for annual exceedance probability analysis of extreme storm events” at the American Society of Civil Engineers (ASCE) sponsored Weather Radar and Hydrology International Symposium on April 7-10 in Reston, VA.

On May 15, Geoffrey Bonnin gave a presentation entitled “Lessons learned from NOAA Atlas 14” at a workshop held at NWS Headquarters in Silver Spring, MD. The “Workshop to Define Needed Extreme Storm Products and Associated Resources” was organized by the Federal Advisory Committee on Water Information's (ACWI) Extreme Storm Events Work Group (ESEWG). Participants reviewed comments received from Federal and State agencies on their views, methods, data sources, tools, etc. regarding extreme storm events. From the workshop the ESEWG will define and prioritize extreme storm products needed for deterministic and risk-informed infrastructure decision making by Federal agencies, and formulate a proposal for with schedules, costs and roles / responsibilities amongst Federal agencies. More information about this meeting is available on the ESEWG website: http://acwi.gov/hydrology/extreme-storm/minutes/index.html.

On April 17, Geoff Bonnin and Dr. Sanja Perica gave a webinar “NOAA Atlas 14 update for Texas” to the Trinity River Flood Management Task Force. Dr. Perica gave a similar presentation entitled “Proposal for Updating Precipitation Frequency Estimates for Texas” at the Texas Floodplain Managers Association conference in Irving, TX on May 30th. Both presentations were given in an effort to secure funding for updating precipitation frequency estimates for Texas.

A member of HDSC, Sandra Pavlovic, gave the following two presentations at the ASCE’s World Environmental & Water Resources Congress, 1-5 June 2014 in Portland, OR: “Intercomparison of methods for estimating areal-reduction factors using a network of gauge stations and radar rainfall data” and “Updated precipitation frequency estimates for the United States: NOAA Atlas 14.”

3. PERSONNEL

Geoff Bonnin, Chief of the Hydrologic Science and Modeling Branch of the NWS Office of Hydrologic Development, retired from the Federal Government on May 31st. Geoff played a key role in the development of NOAA Atlas 14 and the activities of HDSC and so his departure is 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 well as many of you who have been working with him over many years.