HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 July to 30 September 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.

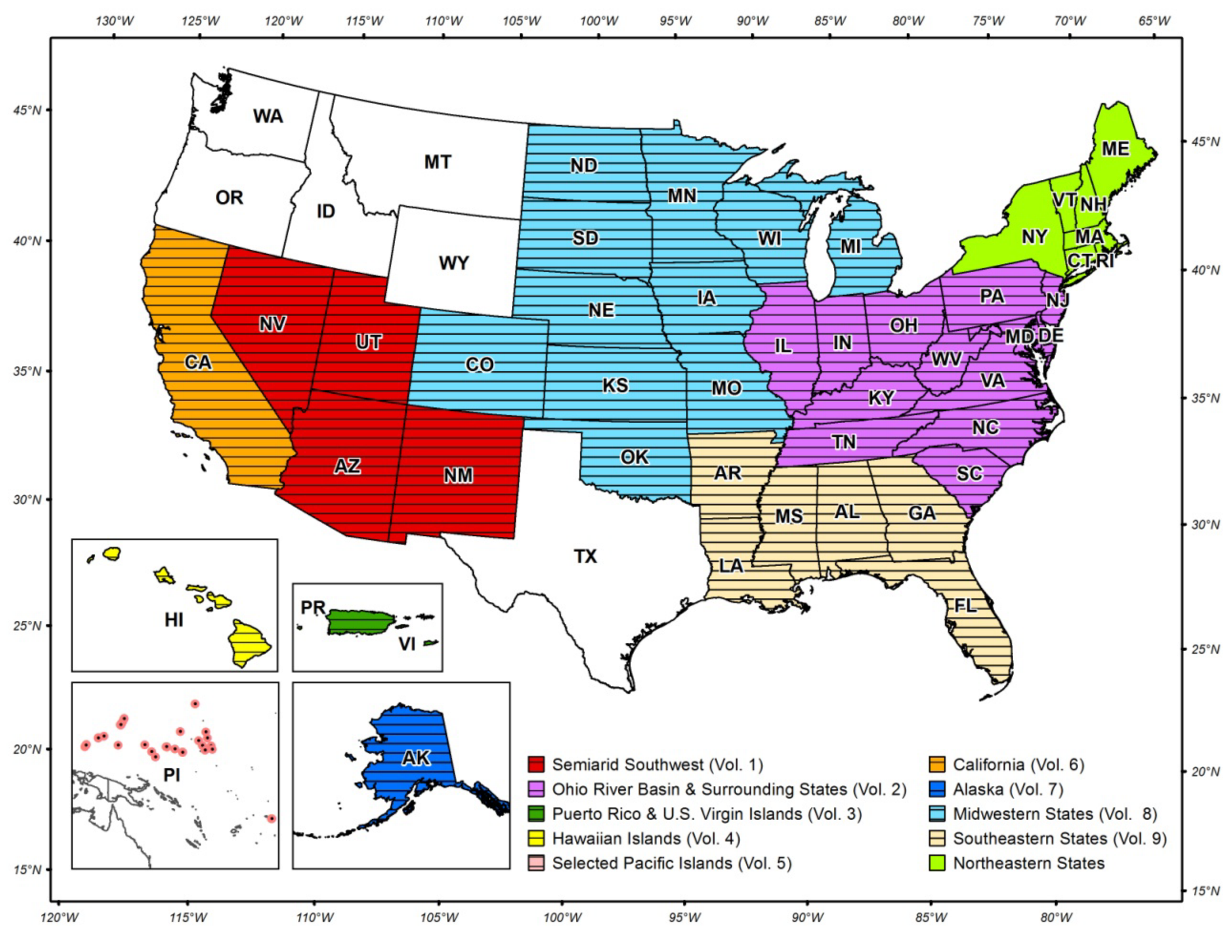

Figure 1. Current project area and project areas included in published NOAA Atlas 14, Volumes 1-9.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 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).

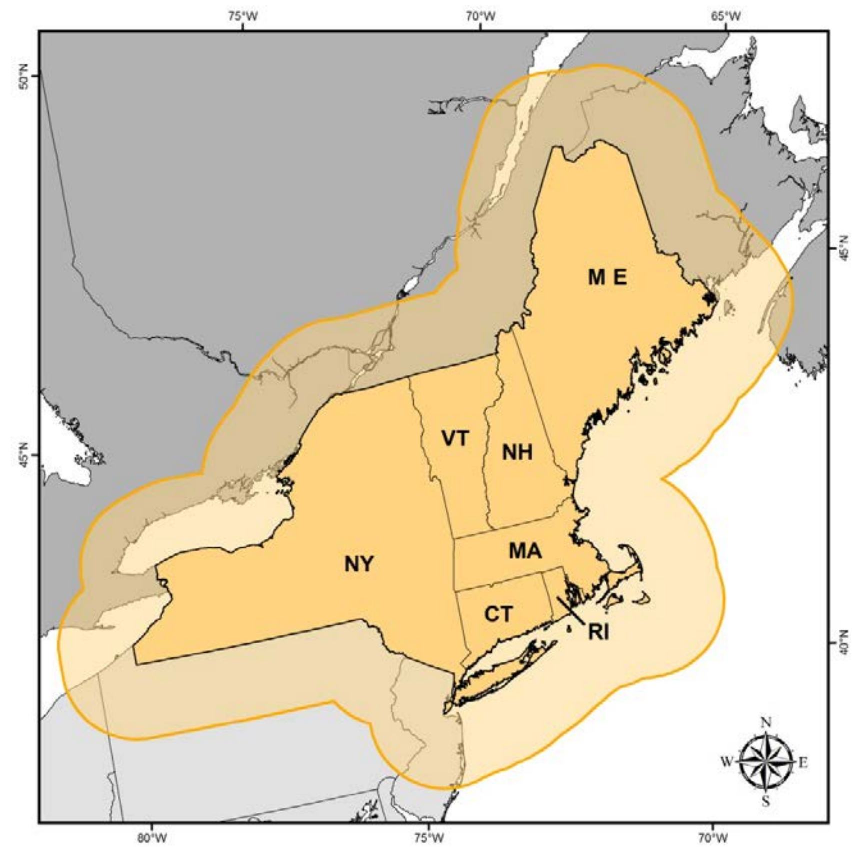

Figure 2. Northeastern precipitation frequency project area (shown in orange).

During this reporting period, we collected and quality controlled recently acquired data, finished regionalization and trend analysis tasks, analyzed spatial patterns in mean annual maxima and developed high-resolution grids of precipitation frequency estimates for durations between 1-hour and 10-days and for average recurrence intervals from 2-year through 100-year for the project area. Those preliminary estimates have been sent to more than 750 individuals for the peer review. The individual sections below describe in more detail major tasks performed during this reporting period.

1.1.1 Peer Review

All NOAA Atlas 14 Volumes are subject to peer review which provides critical feedback on the reasonableness of point precipitation frequency estimates, their spatial patterns, and station metadata. This allows us to incorporate the reviews' local knowledge of rainfall patterns and rain gauge networks into the final product.

On October 1st, 2014 we have published the preliminary results for Volume 10 on the peer review page and we have sent an invitation for the review to more than 750 individuals who expressed interest in the review and/or subscribed to our list server. We welcome comments on estimates, so don't hesitate to contact us if you are interested to participate. The peer review will conclude on Friday, 16 November 2014. At that time, all comments will be consolidated, reviewed and addressed accordingly. We will publish all comments (anonymously) with our resulting action as an Appendix 4 of Volume 10 document.

The peer review web page has been developed for the peer review only. Figure 3 shows the home page for the NOAA Atlas 14 Volumes 10 peer review where the states covered in Volume 10 are marked in dark blue. The preliminary results published on the peer review pages should not be used in design since they are subject to change. The final estimates with supplementary information will be delivered via the Precipitation Frequency Data Server, and will be similar in format to previous volumes. The final product is expected to be published in September 2015.

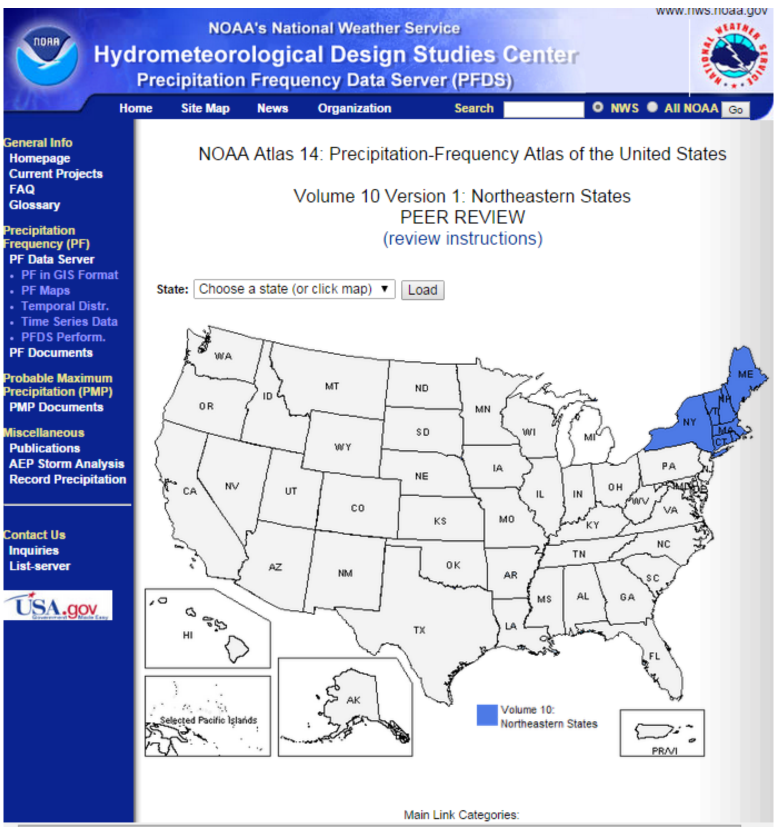

Figure 3. Home page for the NOAA Atlas 14 Volume 10 peer review. States covered in Volume 10 are in dark blue.

As part of the peer review process, we have provided the following NOAA Atlas 14 preliminary products and encourage peer reviewers to make comments on:

1. Station metadata:

   Precipitation measurements were obtained from a number of federal, state, and local agencies for stations inside the project area and approximately a 1-degree buffer around these states (to assist in data quality control and regionalization tasks). All stations considered in the precipitation frequency analysis were provided in two separate excel files and displayed on a Google interactive map for a visual review of station metadata:

   - *Metadata for stations whose data were used to prepare mean annual maximum precipitation maps and/or precipitation frequency estimates*. The list includes information on station name, state, source of data, assigned station ID, latitude, longitude, elevation, and period of record. It also shows if the station was merged with another station and if metadata at the station were changed;

   - *Metadata for stations whose data were collected and examined, but not used in the analysis*. This list contains basic metadata for stations that were not used and the reason why (e.g., because there was another nearby station with a same observations and longer period of record, or station data were assessed as not reliable for this specific purpose, or the station period of record was not long enough and it was not a candidate for merging with any nearby station);

2. At-station depth-duration-frequency (DDF) curves:

   At-station depth-duration-frequency (DDF) curves for stations whose location was retained in analysis were provided for durations between 1-hour and 10-days for average recurrence intervals from 2-year through 100-year at the state-specific web pages (Figure 4). The DDF curves for selected sites are displayed either by clicking on red markers on the map or selecting the specific observation site from the drop-down menu.

3. Cartographic maps:

   Maps of spatially-interpolated precipitation frequency estimates at 30 arc-sec resolution for 2-year and 100-year average recurrence intervals for the 60-minute, 24-hour and 10-day durations were provided for whole project area. Reviews were asked to comment on the overall and local spatial patterns and relative magnitudes. The example of the cartographic map provided for the reviewers is shown in the Figure 5. As noted above, the preliminary estimates should not be used in design since they are subject to change; the cartographic map in Figure 5 is provided only as an example of the product delivered for peer review, not to obtain the estimates from.

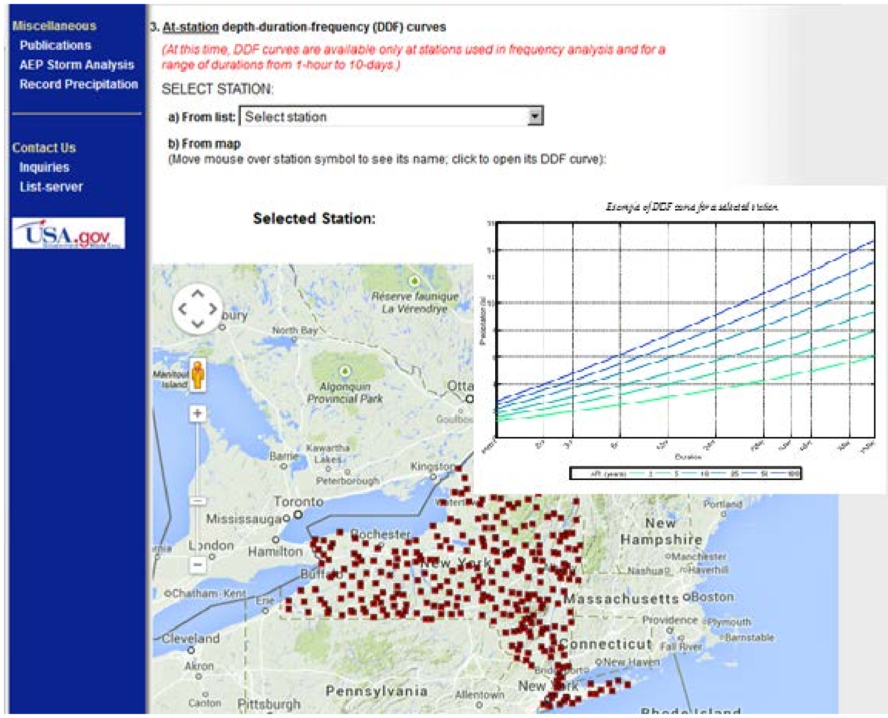

Figure 4. Example of web page showing the section to select a station for review of DDF curves and an example of DDF curve for a selected site.

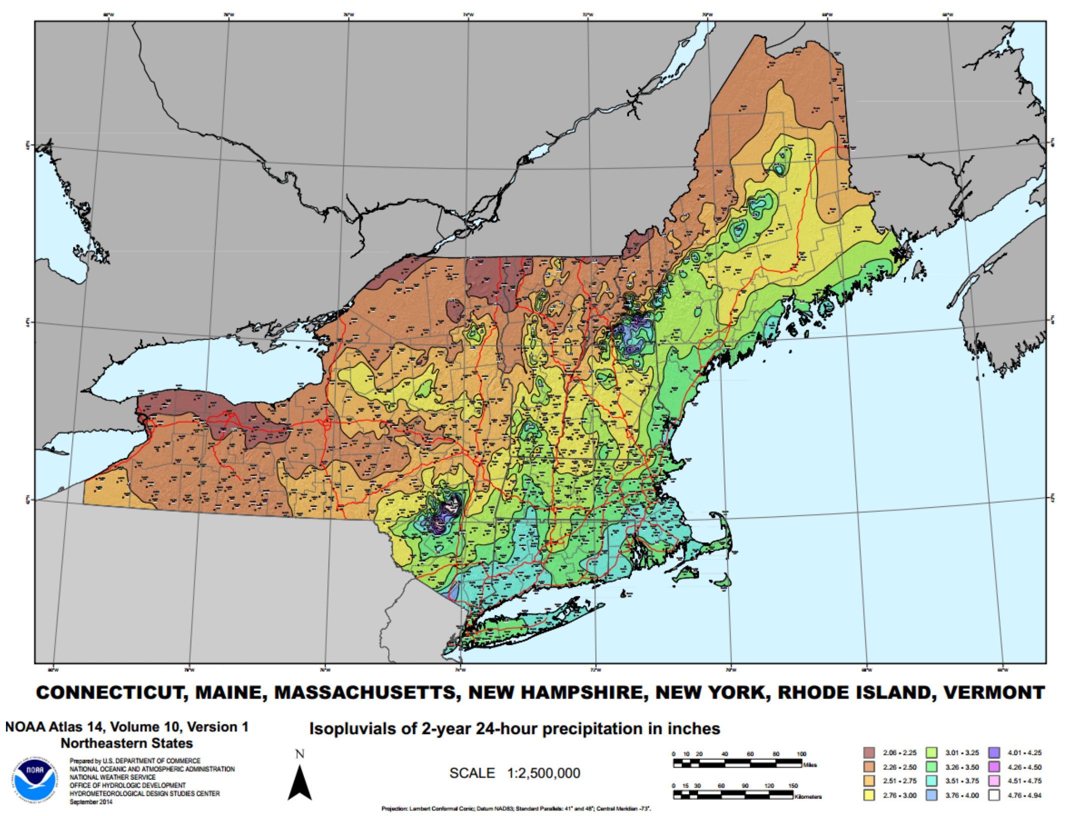

Figure 5. Example of cartographic map provided for peer review.

1.1.2 Data collection and data screening

Table 1 lists all datasets collected so far and the number of stations per recording interval that were retained and not retained in analysis. A station was not retained in the analysis for one of the following criteria: a) located outside the project area; b) station was already included in other datasets; c) station has a record length that is insufficiently long to be used by itself and could not be merged with any nearby station to increase its record length; d) station data is erroneous and unsuitable for AMS extraction; and e) station's coordinates could not be found. Stations retained in analysis represent stations whose partial or complete record was used in the analysis (see Section 1.3 of HDSC quarterly progress report for April - June 2014 report on our procedure for merging two or more nearby stations). If you know about any dataset in addition to those listed in Table 1 below, particularly in areas that do not have good coverage such as Maine or any mountainous area, please contact us at HDSC.Questions@noaa.gov.

Table 1. List of collected datasets and the number of stations per recording interval retained and not retained in analysis.

Source of data	Reporting interval	Number of stations not retained	Number of stations retained
U.S. Department of Agriculture: Agricultural Research Service (ARS)	MN15	17	3
Automated Surface Observing Systems (ASOS)	HLY	0	2
	MN15	40	25
Boston Water and Sewer Commission	HLY	6	0
	MN15	6	0
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (COCORAHS)	DLY	2,564	73
Citizen Weather Observers Program (CWOP)	HLY	1	0
	MN15	5	1
Environment Canada	DLY	2,469	511
	HLY	420	116
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	DLY	27	39
Lyndon State College, Lyndonville, VT	MN15	0	1
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	DLY	81	2
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	DLY	44	0

Source of data	Reporting interval	Number of stations not retained	Number of stations retained
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	DLY	183	0
Massachusetts Department of Conservation and Recreation	DLY	1	12
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	DLY	44	18
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	44 14 5	77 19 15
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	130 23 9	111 29 21
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	111 13 4	176 31 23
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	95 11 6	116 31 26
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	34 17 1	80 23 18
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	357 77 30	454 106 87
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY	37	24
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	12 4 2	7 4 2
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY HLY MN15	145 66 35	194 88 70

Source of data	Reporting interval	Number of stations not retained	Number of stations retained
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY	17	17
	HLY	3	4
	MN15	0	3
NOAA, National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC)	DLY	82	89
	HLY	8	26
	MN15	5	22
New Hampshire Department of Transportation (NHDOT)	MN15	9	0
Office of the New Jersey State Climatologist at Rutgers University: NJ Mesonet	HLY	5	2
Office of the New Jersey State Climatologist at Rutgers University: NJ SafetyNet	HLY	4	1
New York City Department of Protection (NYCDEP)	DLY	0	7
	HLY	19	6
Eastern New York Observing Network	DLY	0	2
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	HLY	31	9
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	DLY	1	0
NCDC: U.S. Climate Reference Network (USCRN)	DLY	11	0
	HLY	8	3
USGS Massachusetts-Rhode Island Water Science Center	DLY	5	0
	HLY	1	0
	MN15	11	4
USGS Maine Water Science Center	DLY	12	4
USGS New Hampshire-Vermont Water Science Center	DLY	6	0
USGS New York Water Science Center	DLY	1	0
Earth Network	HLY	1,986	0
Grand Total		**9,415**	**2,834**

Table 2 shows total number of stations formatted and the number of stations currently retained for frequency analysis 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.

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	8,526	2,013
1-hour	3,217	500
15-minute	506	321

1.1.3 Analysis of spatial patterns of mean annual maxima

Mean annual maximum (MAM) grids serve as the basis for deriving gridded precipitation frequency estimates at different frequencies and durations. The MAM grids were developed from at-station MAM values by Oregon State University's PRISM Climate Group using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM).

HDSC investigated at-station MAMs (stations with more than 10% difference between observed and expected MAM values identified by jackknife analysis performed by the PRISM Climate Group, or any other at-station MAM values that resulted in several contours around the observation site, spatial bullseyes) and spatial patterns in intermediate MAM grids for the 1-hour, 1-day and 10-day durations. As a result of our review, some at-station MAM estimates were adjusted or added to the dataset to better anchor the spatial interpolation in areas of varied terrain and/or where the lack of stations or short records unduly influenced expected spatial patterns, particularly at hourly durations. Several iterations with the PRISM Group were required to ensure satisfactory MAM estimates interpolated to a 30-arc grid for 1-hour to 10-day durations.

1.1.4 Regional frequency analysis

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 number of stations used to define a region should be large enough to smooth variability in at-station estimates, but also small enough that regional estimates still adequately represent local conditions. 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.

Regions were created for each gauged location in the project area. Initial regions for each station were formed by grouping the closest 10 stations. Stations were then 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, etc. and assessment of similarities/dissimilarities in the progression of relevant L-moment statistics across durations compared with other stations in the region. During the process, some inconsistent stations were removed from the analysis if their records were short, particularly if a nearby station had a much longer record.

Precipitation frequency estimates for each station were computed using the Generalized Extreme Value (GEV) distribution parameterized via regional L-moment approach. More details on this technique can be found in Section 4 of NOAA Atlas 14 Volume 9 document.

1.1.5 Analysis of spatial patterns in 2-year and 100-year precipitation frequency estimates

HDSC-developed spatial interpolation technique was used to convert mean annual maximum grids into grids of precipitation frequency estimates. More details on this technique can be found in Section 4 of NOAA Atlas 14 Volume 9 document. The 2-year and 100-year precipitation frequency estimates at 1-hour, 1-day and 10-day durations were then analyzed for any bullseyes or inconsistencies relative to expected spatial patterns.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2014)

The peer review process of Volume 10 will be completed by the next reporting period. HDSC will consolidate, review and start addressing comments received from reviewers. Additionally, we will work on the following tasks: trend analysis, temporal distribution analysis, seasonality analysis, and rainfall 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, independence, consistency across durations, duplicate stations, candidates for merging) [Complete]

Regionalization and frequency analysis [Complete]

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

Peer review [In progress]

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 (Jul - Sep 2014)

As reported in the previous progress report, activities on this project have been put on hold in June 2014 while the reorganization of the NWS headquarters is underway. We anticipate that the NWS reorganization will be complete in early 2015. For more information on the tasks accomplished to date, please see Section 2 of HDSC quarterly progress report for April - June 2014 report.

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2014)

No activities are planned for the next reporting period.

2.3 PROJECT SCHEDULE

The ARF project is 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 (Jul - Sep 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.

During this reporting period, we continued the evaluation of IDFs from various types of non-stationary models against the current NOAA Atlas 14 stationary model. 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 have been investigated.

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.

For that reason, during this progress report, we performed analysis on the partial duration series (PDS) data that is similarly done on the AMS. Then we compared the performance of the AMS and PDS models in terms of the uncertainty of T-year event estimators in the cases of estimation with the maximum likelihood method and L-moments method. For the PDS model, we applied a generalized Pareto (GP) distribution as it has been shown that the assumptions of, respectively, GP distributed exceedance magnitudes and a Poisson distributed number of threshold exceedances in the PDS imply the corresponding AMS to follow the generalized extreme value (GEV) distribution with the same shape parameter as in the GP distribution.

3.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct- Dec 2014)

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

3.3 PROJECT SCHEDULE

Expected completion date for this pilot project is February 2015.

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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.

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/.

During this reporting period, HDSC preformed the storm analysis for two storm events: the 13 August 2014 event in Islip, New York and the 19 August 2014 event near Phoenix, Arizona. For these storm events, we look at a range of durations and create a map for the one that shows the lowest AEPs for the largest area. Maps do not represent isohyets at any particular point in time but rather isolines of AEPs within the whole event.

Figure 6 shows the AEPs of the worst 3-hour rainfall from the 13 August 2014 event in Islip, New York (Figure 6). For this analysis, the point rainfall frequency estimates are based on the preliminary NOAA Atlas 14 Volume 10 estimates and the rainfall observations are based on [Dual-Polarization radar QPE data.]()

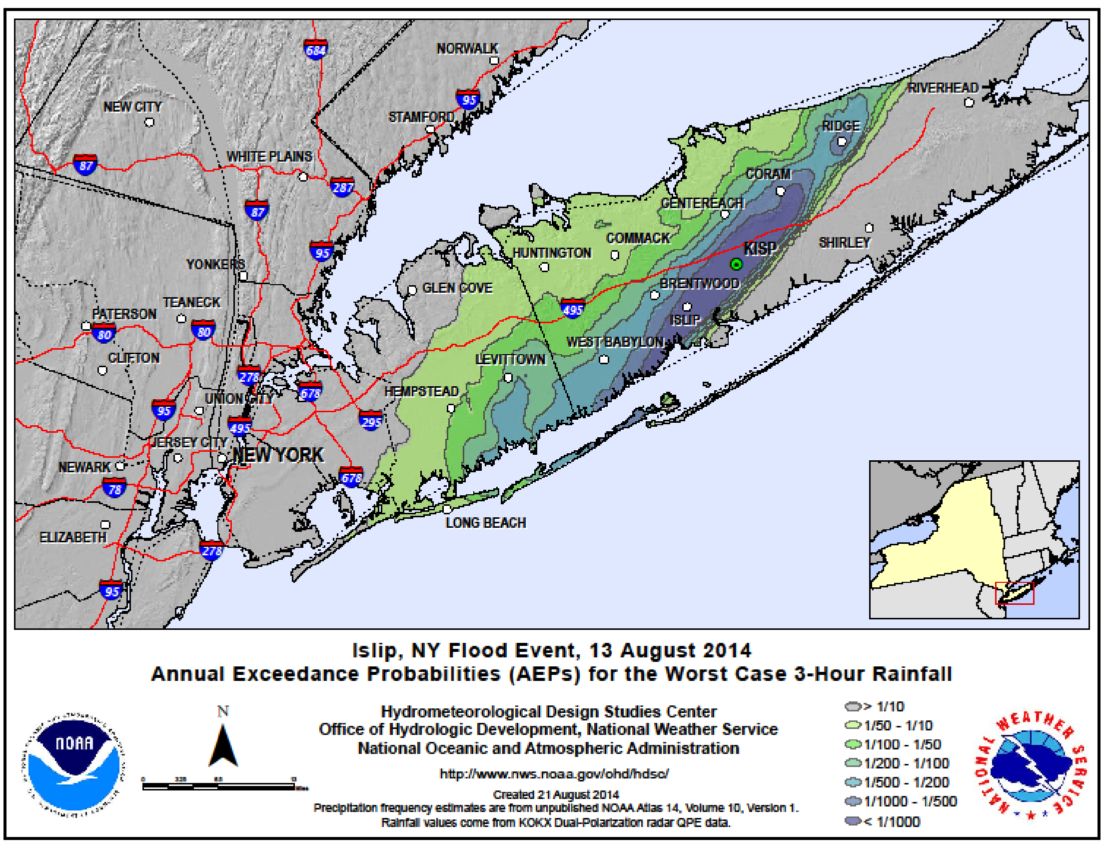

Figure 6. Annual exceedance probabilities for the worst case 3-hour rainfall for the 13 August 2014 event in Islip, New York.

Figure 7 shows the AEPs of the worst 12-hour rainfall from the 19 August 2014 event near Phoenix, Arizona. The point rainfall frequency estimates in this analysis are based on NOAA Atlas 14 Volume 1 Version 5 and the rainfall observations are based on the [Dual-Polarization radar QPE data.](#)

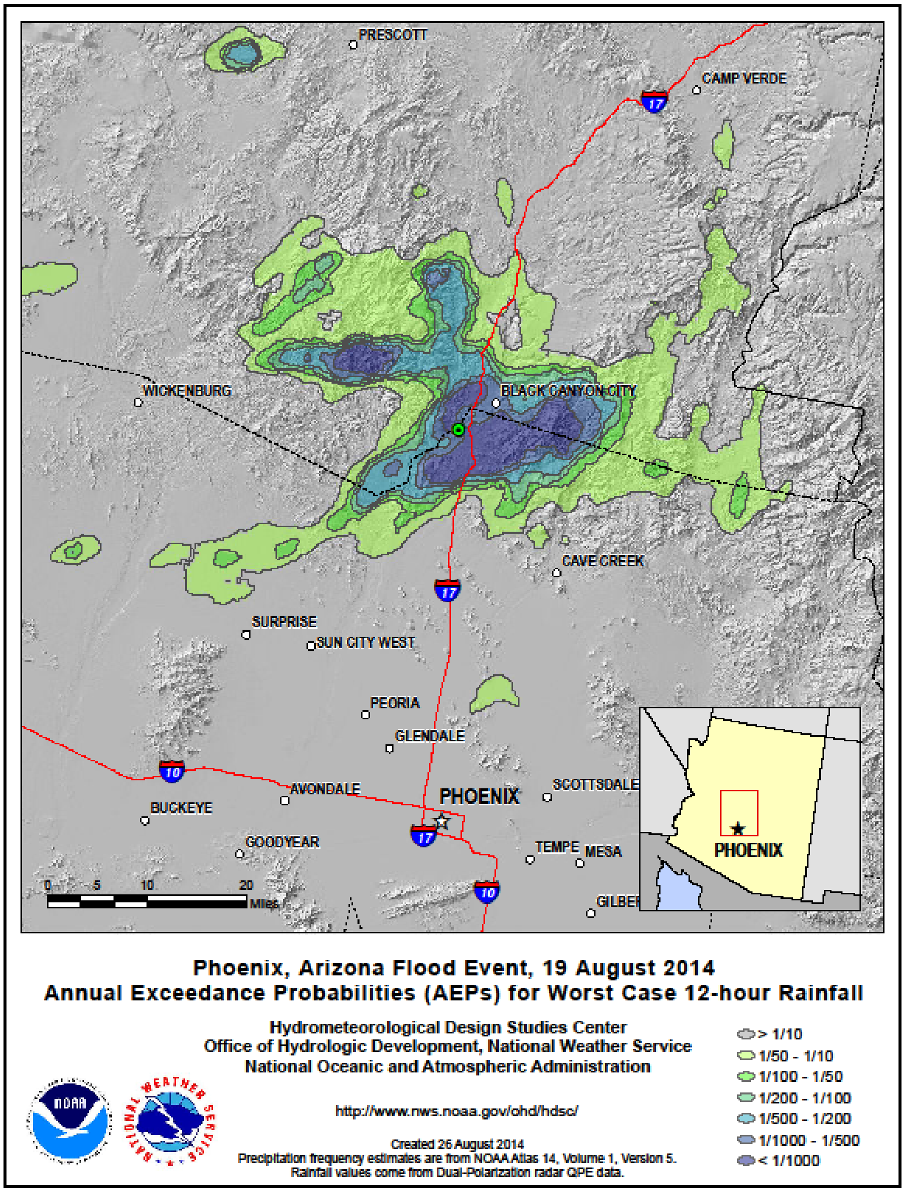

Figure 7. Annual exceedance probabilities for the worst case 12-hour rainfall for the 19 August 2014 event in Phoenix, Arizona.