HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 October to 31 December 2016

Office of Water Prediction
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Silver Spring, Maryland

January 2017

DISCLAIMER

The data and information presented in this report are provided only to demonstrate current progress on the various tasks associated with these projects. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any other purpose does so at their own risk.

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I. INTRODUCTION

The Hydrometeorological Design Studies Center (HDSC) within the Office of Water Prediction (OWP; formerly, Office of Hydrologic Development and National Water Center)[1] of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) has been 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. Figure 1 shows the states or territories associated with each of the Volumes of the Atlas. To date, we have updated precipitation frequency estimates for Arizona, Nevada, New Mexico and Utah (Volume 1, 2004), Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virginia (Volume 2, 2004), Puerto Rico and U.S. Virgin Islands (Volume 3, 2006), Hawaiian Islands (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), California (Volume 6, 2011), Alaska (Volume 7, 2011), Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin (Volume 8, 2013), Alabama, Arkansas, Florida, Georgia, Louisiana, and Mississippi (Volume 9, 2013), and Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Volume 10, 2015). Since May 2015, HDSC has been working on updating precipitation frequency estimates for the state of Texas. We expect to publish them in mid-2018 in NOAA Atlas 14, Volume 11.

Funding for HDSC work comes from external sources. For recent volumes, most of the funds have come from the U.S. Army Corps of Engineers (USACE), Federal Highway Administration (FHWA) and State Departments of Transportation. These funds flow through the Transportation Pooled Fund (TPF) Program, which is set up to allow interested federal, state, and local agencies and other organizations to combine resources to support transportation relevant research studies. This requires only a single agreement between NWS and FHWA rather than many agreements with each entity providing funds. OWP has been working with FHWA and several Northwestern state agencies on securing funding to extend NOAA Atlas 14 coverage to the remaining five northwestern states: Idaho, Montana, Oregon, Washington, and Wyoming in Volume 12. An updated solicitation for this project will be listed on the TPF web page in the near future. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

[1]*The Office of Hydrologic Development reorganized into the National Water Center in May 2015 which was recently renamed as the Office of Water Prediction (OWP) with locations in Silver Spring, MD, Tuscaloosa, AL, and Chanhassen, MN.*

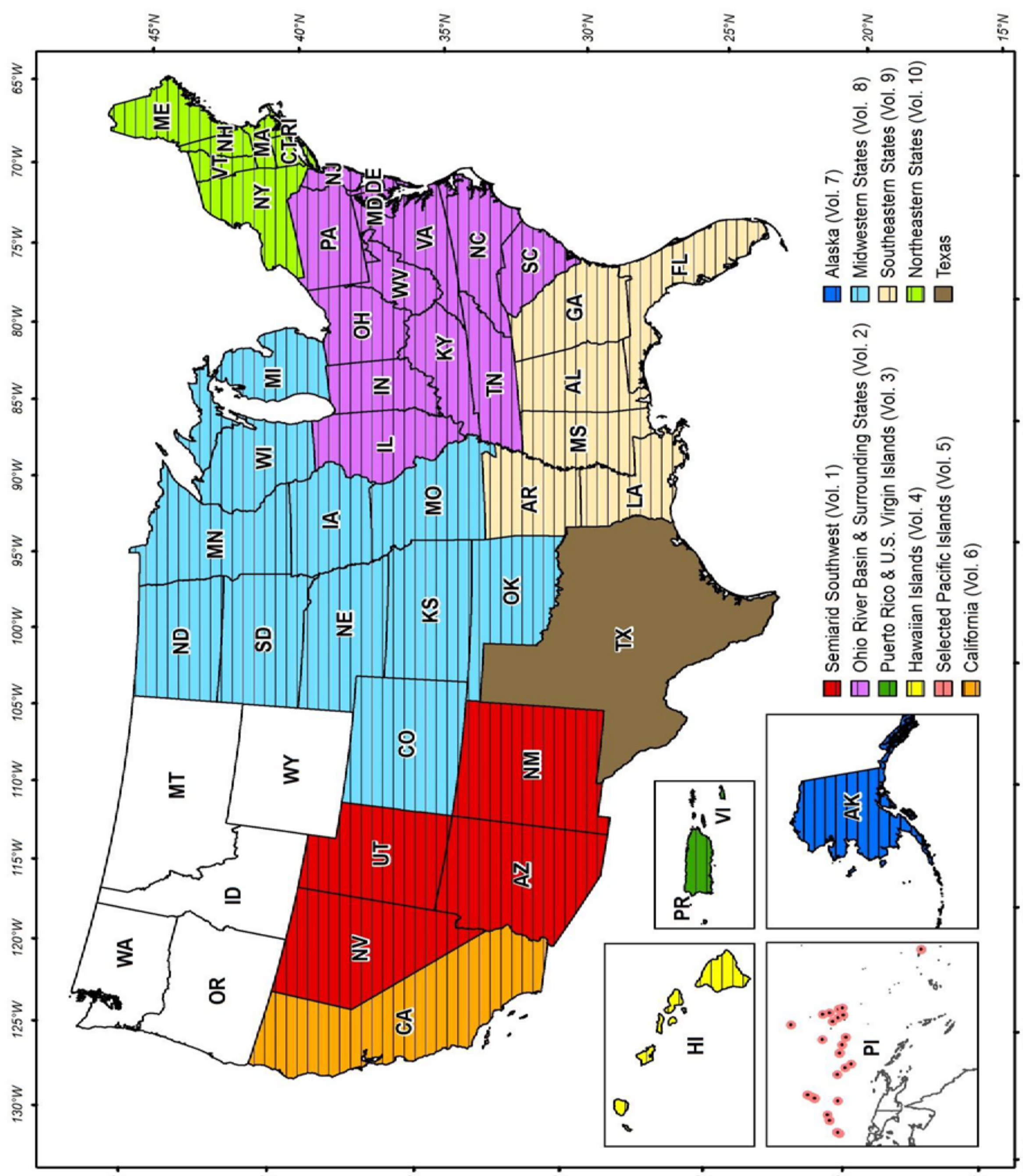

Figure 1. Current project area for Volume 11 (Texas) and project areas included in published Volumes 1 to 10.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

1.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2016)

Precipitation frequency estimates for the following seven northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont were published on September 30, 2015, as NOAA Atlas 14, Volume 10. The estimates for any location in the project area, along with all related products except documentation, are available for download in a variety of formats through the Precipitation Frequency Data Server (PFDS).

Work on documentation describing the station metadata, data, and project methodology has been put on hold as of October 2015, due to funding issues. Those issues have been resolved during this reporting period.

1.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2017)

We restarted the work on documentation in this quarter. We expect to release the NOAA Atlas 14 Volume 10 document by the end of the next reporting period. We will publish the document here: http://www.nws.noaa.gov/oh/hdsc/currentpf.htm.

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 [Complete]

Revision of PF estimates [Complete]

Remaining tasks (e.g., development of gridded precipitation frequency estimates, confidence intervals, development of PFDS web pages) [Complete]

Web publication of estimates [Complete]

Web publication of Volume 10 document [March 2017]

2. PRECIPITATION FREQUENCY PROJECT FOR TEXAS

2.1 PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2016)

The extended project area for the NOAA Atlas 14 Volume 11 precipitation frequency project includes the state of Texas and approximately a 1-degree buffer around the state (Figure 2). We began this project in May 2015 and expect to complete it in mid-2018.

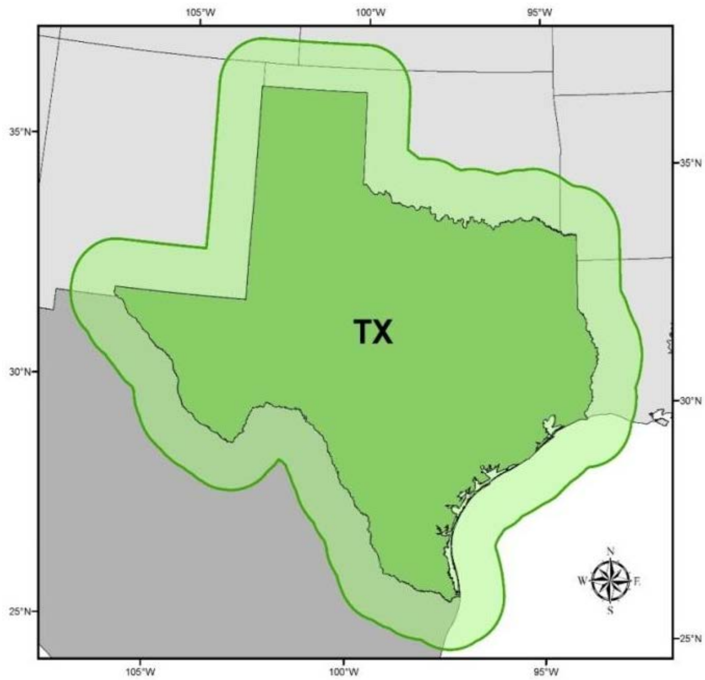

Figure 2. NOAA Atlas 14, Volume 11 extended project area.

During this reporting period, we continued data collection, digitization and formatting. We made significant progress with annual maximum series quality control task. Below, we describe in more detail the major tasks performed during this reporting period.

2.1.1. Data collection and formatting

The primary source of data for NOAA Atlas 14 Volumes is the NOAA's National Centers for Environmental Information (NCEI), but we recognize that the NCEI's precipitation data may not be sufficient to accomplish the objectives of NOAA Atlas 14. Therefore, for each project area, we also collect data from other Federal, State and local agencies.

For this project area, we are trying to assemble all reliable precipitation data for stations in Texas, as well as in adjacent portions of neighboring states (Arkansas, Louisiana, New Mexico, and Oklahoma) and also in Mexico. Since we started this project, we have contacted numerous agencies for assistance with the data. During this reporting period, we continued reviewing the information provided to us and contacting other agencies which were indicated as additional sources of potentially useful data.

We format all data to a common format at one of three base durations (1-day, 1-hour, 15-minute) that correspond to the original reporting period. Data recorded at variable time steps are formatted at 15-minute increments. So far, we have formatted and retained data for 10,455 stations from 31 datasets; they are listed in Table 1. The total number of stations, available so far, per recording period is listed in Table 2.

Table 1. Datasets formatted as of this time.

Source of data and dataset: network name	**Recording period**
NCEI: Automated Surface Observing System (ASOS)	1-min
NCEI: DSI 3260	15-minute
NCEI: DSI 3240	1-hour
NCEI: Global Historical Climatology Network (GHCN)	1-day
NCEI: Quality Controlled Local Climatological Data (QCLCD)	1-hour
NCEI: Unedited Local Climatological Data (ULCD)	1-hour
City of Dallas ALERT Network	varying
Edwards Aquifer Authority	1-hour
Guadalupe-Blanco River Authority	6-min
Harris County Flood Control District's Flood Warning System	varying
Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network	varying
Lower Colorado River Authority Regional Meteorological Network	varying
Midwestern Regional Climate Center: CDMP 19th Century Forts and Voluntary Observers Database	1-day
National Atmospheric Deposition Program (NADP)	1-day
National Estuarine Research Reserve System (NERRS)*	15-minute, 1-hour
NWS Hydrometeorological Automated Data System	1-hour
Oklahoma Mesonet Observation Network*	5-min, 1-day
Sabine River Authority Precipitation Dataset	1-day
Servicio Meteorologico Nacional, Mexico	1-day
Tarrant Regional Water District (Greater Fort Worth area)/ Tarrant County Urban Flood Control Network	15-minute, 1-hour
Texas Commission on Environmental Quality: Air Quality Network*	1-hour
Texas Evapotranspiration Network	1-hour,1-day
Texas Water Development Board	1-hour,1-day
Titus County Fresh Water Supply District No. 1	1-day
U.S. Bureau of Reclamation: HydroMet	1-hour, 1-day
US Dept. of Agriculture (USDA): Agricultural Research Service (ARS)	varying
USDA, Forest Service: Remote Automated Weather Station (RAWS) Network	1-hour
USDA , National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)*	1-hour
USGS Nation Water Information System (NWIS)	15-minute
West Texas Mesonet	1-min, 15-minute

Table 2. Number of stations per recording period formatted so far.

Recording period	Number of stations
1-day	5,944
1-hour	3,150
15-minute, varying	1,361
TOTAL	**10,455**

Table 3 contains information on the status of collection and formatting tasks for additional datasets. Datasets indicated as "not used" generally contain information already included in other datasets, data assessed as not reliable for this specific purpose, or stations with very short periods of record deemed unsuitable for merging with any nearby station.

Table 3. Status of data collection for additional datasets.

Source of data and dataset/network name (when available)	Status
City of Austin ALERT Network	contacted with data request
Lavaca/Navidad River Authority Gage Network	
San Antonio River Authority	
International Boundary and Water Commission	need contact information
Bexar County Urban Flood Control Network	not used
Meteorological Assimilation Data Ingest System (MADIS)	
Mexico Hourly Data downloaded from Iowa IEM	
NCEI: Automated Weather Observing System (AWOS)	
NCEI: U.S. Climate Reference Network (USCRN)	
Northeast Texas Municipal Water District (NETMWD)	
PivoTrac Monitoring, LLC	
Road Weather Information System (RWIS)	
Union Pacific Railroad Weather Station Network	

Locations of daily stations formatted and processed as of this time are shown in Figure 3. Only stations with at least 30 years of AMS data (shown as red circles) will be considered for frequency analysis, although allowances may be made for isolated stations. Stations with less than 30 years of data, shown as black dots in the figure, will still be used in various quality control tasks; some of those stations may end up being used in the analysis through merging their data with data from nearby stations and from datasets not formatted yet. Similarly, Figures 4 and 5 show locations of stations recording at 1-hour and at sub-hourly durations, respectively, where stations with less than 20 years of AMS data are shown as black dots. Datasets with an asterisk in Table 1 are formatted but not processed yet, so stations from those datasets that pass the minimum number of data-years requirement are not plotted on the maps.

We would like to thank all of those who responded to our inquiry and/or provided the data. We still welcome any information on the data for this project area. Please contact us at

HDSC.Questions@noaa.gov if you know about any datasets in addition to those listed in Tables 1 and 3, particularly in areas of low station density (see Figures 3 to 5).

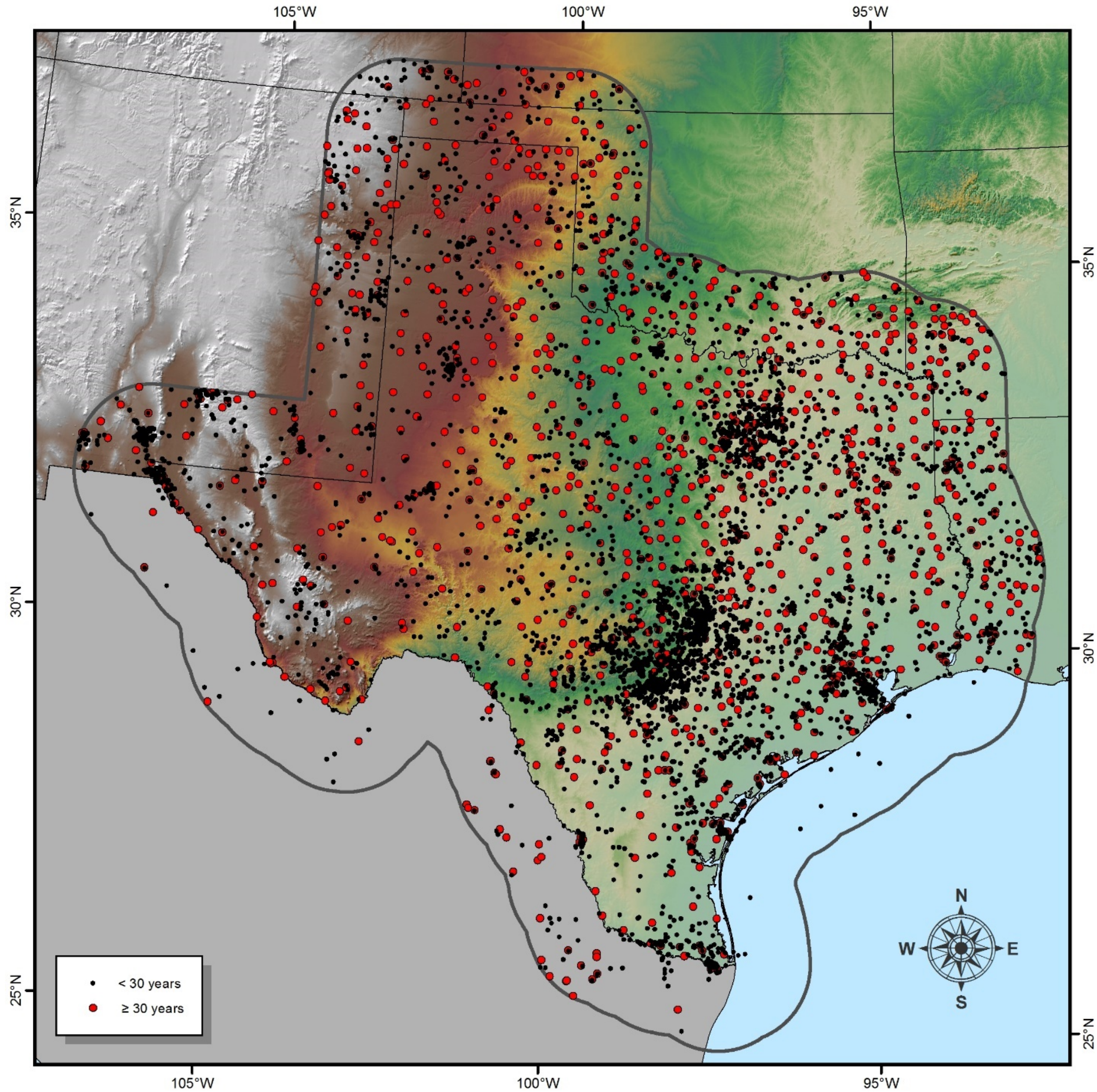

Figure 3. Map of stations recording at 1-day interval formatted as of this time. As of now, only stations shown as red circles (1,054 of 5,944 stations) will be considered in frequency analysis for durations between 1 day and 60 days (see also comment in the paragraph above).

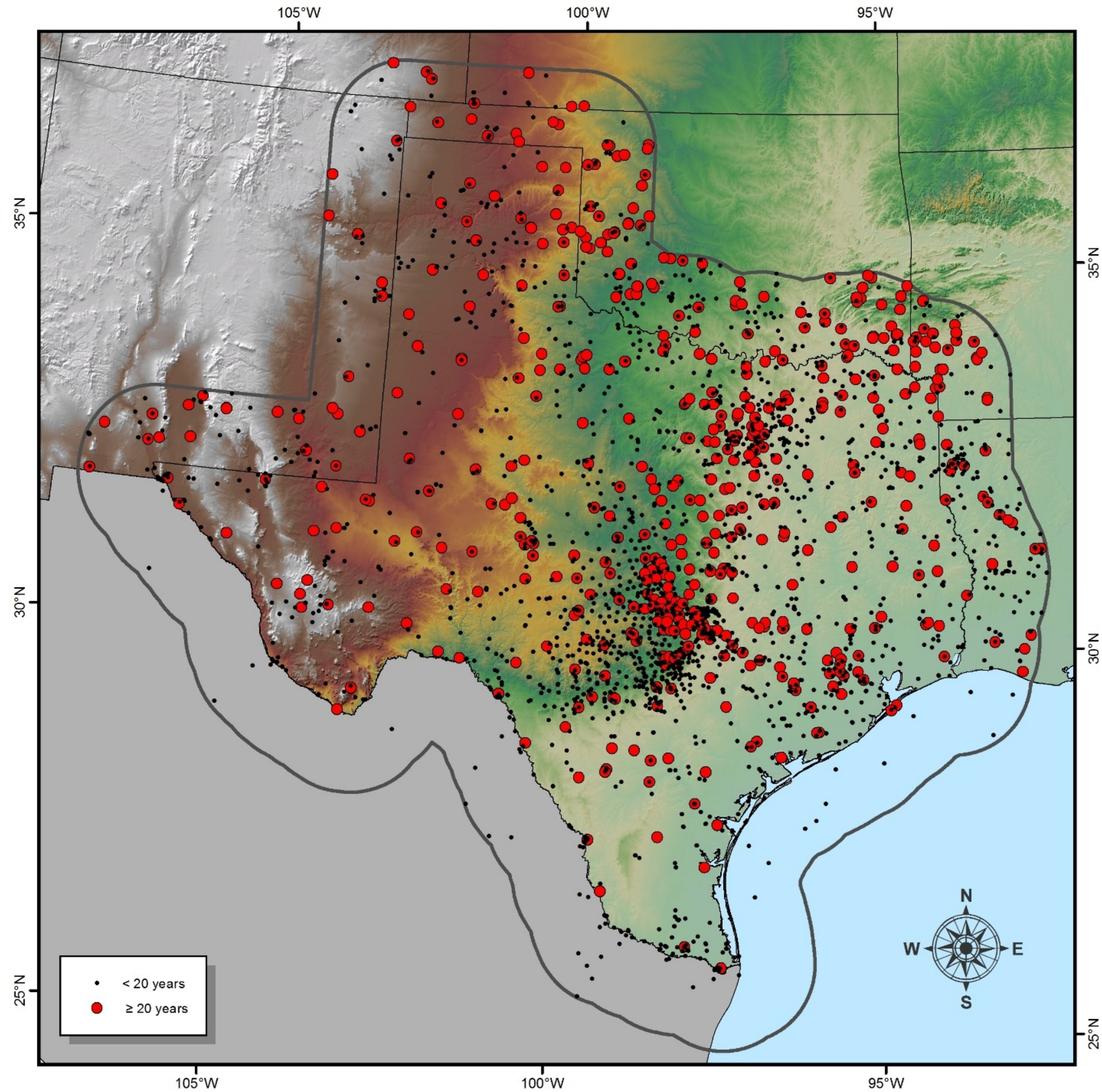

Figure 4. Map of stations recording at 1-hour interval formatted as if this time. Only stations shown as red circles (574 of 3,150 stations) will be considered in frequency analysis for durations between 1 hour and 60 days.

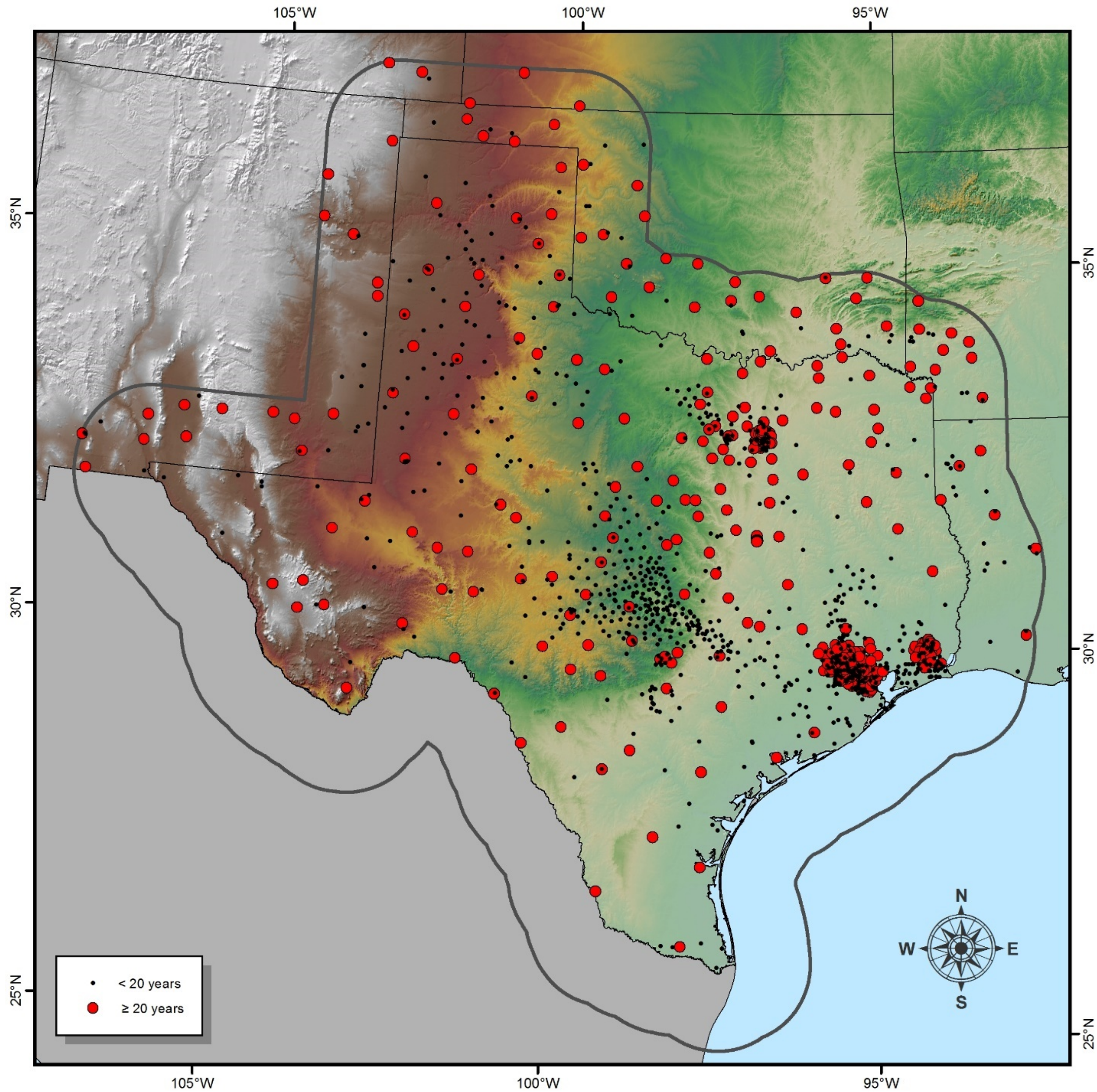

Figure 5. Map of stations recording at sub-hourly intervals formatted as of this time. Only stations shown as red circles (283 of 1,361 stations) will be considered in frequency analysis for durations between 15 minutes and 60 days.

2.1.2. Data digitization

In this reporting period, with the help of students/interns working with the U.S. Army Corps of Engineers - Fort Worth District, we continued to digitize additional precipitation data from the NCEI's Climate Database Modernization Program (CDMP). The focus up until this point has been mostly on extending records for hourly stations in urban areas, but this work will also apply to hourly and daily stations in data scarce areas and stations with significant periods of record missing. A summary of the work completed and in progress thus far with the stations' names, recording intervals and periods of record digitized is shown in Table 4.

Figure 6 shows, as an example, the effect of newly digitized hourly data on 1-day AMS for NCEI's daily station Taylor (station ID 41-8861; also merged with nearby NCEI's station 41-8862). For this station, the daily record was extended for an additional 27 years (1903-1929). As is evident from the figure, several of the largest values in the AM series, including the AM from the September 7-11, 1921 extreme event, come from the newly digitized data.

Table 4. Status of digitization work (indicates digitization in progress)*

Station name	Recording interval	Period digitized
Abilene	1-hour	1906-1940
Amarillo	1-hour	1904 -1940
Brackettville/Fort Clark	1-day	1853-1899
Corpus Christi	1-hour	1902-1940
El Paso	1-hour	1906 -1940
Fort Worth	1-hour	1903-1940
Galveston*	1-hour	1892-1940
Hearne/Valley Junction	1-day	1888-1946
Houston*	1-hour	1910-1940
Houston*	1-day	1888-1909
San Antonio	1-hour	1903-1940
Taylor	1-hour	1903-1932

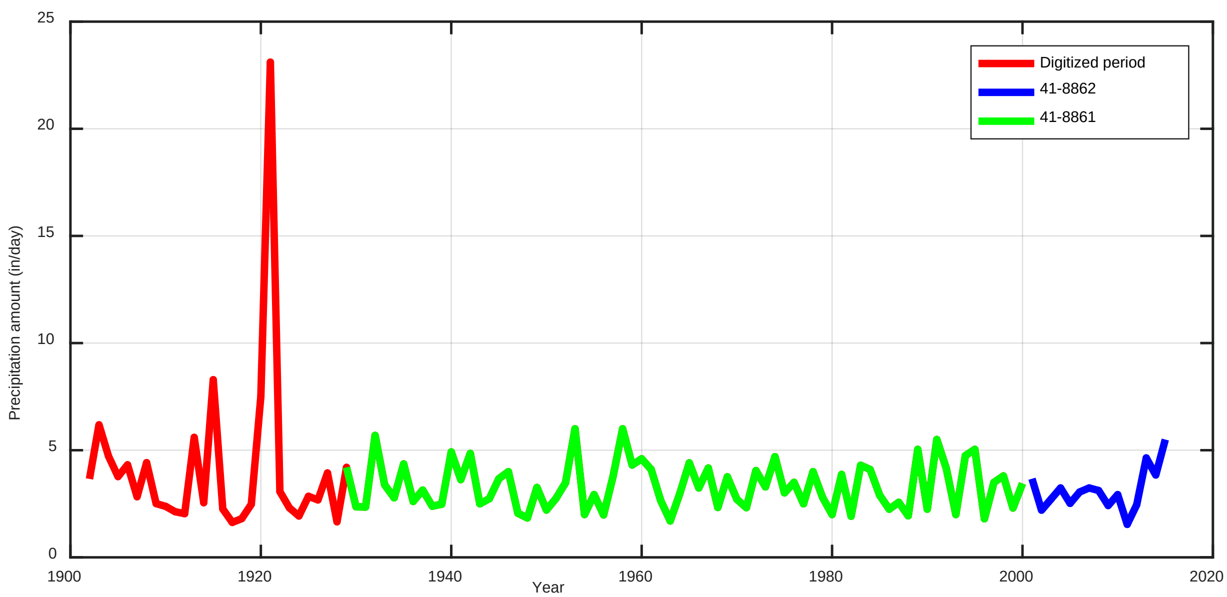

Figure 6. 1-day annual maximum series for Taylor station (41-8861 in green and 41-8862 in blue). AM from the newly digitized hourly data are shown in red.

2.1.3. Annual maximum series (AMS) extraction

The precipitation frequency analysis approach we used in this project is based on AMS analysis across a range of durations. AMS for each station whose data were formatted were obtained by extracting the highest precipitation amount for a particular duration in each successive calendar year. Calendar year was used in this project area based on the distribution of heavy precipitation events so that a year begins and ends during a relatively dry season. AMS at stations formatted during this period were extracted for all durations equal to or longer than the base duration (or reporting interval) up to 60 days. The criteria for extraction were designed to exclude maxima if there were too many missing or accumulated data during the year, especially during critical months when precipitation maxima were most likely to occur. All annual maxima that resulted from accumulated data were flagged and screened to ensure that the incomplete data did not result in erroneously low maxima.

2.1.4. Station screening

a. Quality control of metadata and location screening

We finished screening the basic metadata (latitude, longitude and elevation) for stations formatted in this period 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 100 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. We will provide original and revised coordinates for all stations used in the analysis in Appendix 1 of the NOAA Atlas 14, Volume 11 document.

b. Co-located station cleanup

During this reporting period, we completed co-located station cleanup for newly added stations. 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 effort, we implemented 309 simple and special corrections to the data.

c. Nearby station cleanup and merges

For this task, we define nearby stations 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. Additionally, stations with duplicate data or stations with data found to be unreliable are marked for deletion.The nearby station cleanup and merge effort for the daily stations is complete**.** We implemented 286 merges/extensions, and 69 deletes as a result of this task.

2.1.5. AMS quality control

Since AMS 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.

We use different statistical tests to identify high and low outliers in the distribution of at-station precipitation AMS. All identified outliers and other questionable maxima at base durations (15-minute, 1-hour and 1-day) are now being verified. First, they are mapped with concurrent measurements at nearby stations. If they cannot be confirmed, they are investigated further using information from climatological observation forms, monthly storm data reports and other historical weather event publications obtained primarily from the NCEI's Environmental Document Access and Display System (EDADS).

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2017)

We will continue work on digitization task and finish various quality control and data reliability tests. We'll also develop an initial set of regional frequency estimates for durations between 15 minutes and 60 days and ARI between 1 year and 100 years at gauged locations.

2.3 PROJECT SCHEDULE

Data collection, formatting, and initial quality control [Done, but still collecting additional datasets]

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) [In progress; revised to February 2017]

Regionalization and frequency analysis [Revised to April 2017]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [June 2017]

Peer review [August 2017]

Revision of PF estimates [January 2018]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [March 2018]

Web publication [April 2018]

III. OTHER

1. EXCEEDANCE PROBABILITY ANALYSIS FOR SELECTED STORM EVENTS

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events for which observed precipitation amounts for at least one duration have AEP of 1/500 or less over a large area. AEP is the probability of exceeding a given amount of rainfall for a given duration at least once in any given year at a given location. It is an indicator of the rarity of rainfall amounts and is used as the basis of hydrologic design. For the AEP analysis, we look at a range of durations and select one or two critical durations which show the lowest exceedance probabilities for the largest area, i.e., the "worst case(s)." Since, for a given event, the beginning and end of the worst case period are not necessarily the same for all locations, the AEP maps do not represent isohyets at any particular point in time, but rather within the whole event. The maps, usually accompanied with extra information about the storm, are available for download from the following page: AEP Storm Analysis. During this reporting period, we analyzed annual exceedance probabilities (AEPs) of the worst case rainfall for the October's 2016 Hurricane Mathew event.

The underlying data for the AEP analyses are rainfall observations and point rainfall frequency estimates at 30-arcsecond resolution for a range of durations and AEPs. Whenever feasible, gridded rainfall observations are developed from rainfall data collected from all available reporting rain gauges at the time when the map is created (such as rain gauges from the NCEI's Climate Data Online. Alternatively, we rely on the National Centers for Environmental Prediction's multi-sensor precipitation Stage IV analysis product and the NCEI's Next Generation Weather Radar (NEXRAD) product. Rainfall frequency estimates typically come from the NOAA Atlas 14 Volumes.

1.1. HURRICANE MATTHEW, OCTOBER 2016

Hurricane Matthew, a category five hurricane when it was at maximum intensity while in the Caribbean Sea, passed through the southeastern United States in the period between September 28, 2016 and October 10, 2016, causing devastating flooding that resulted in the loss of human life and destruction of private and public property, and infrastructure. HDSC analyzed annual exceedance probabilities (AEPs) for this event for a range of durations and determined that the 24-hour period showed the lowest exceedance probabilities for the largest area. Areas that experienced the maximum 24-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the map in Figure 7.

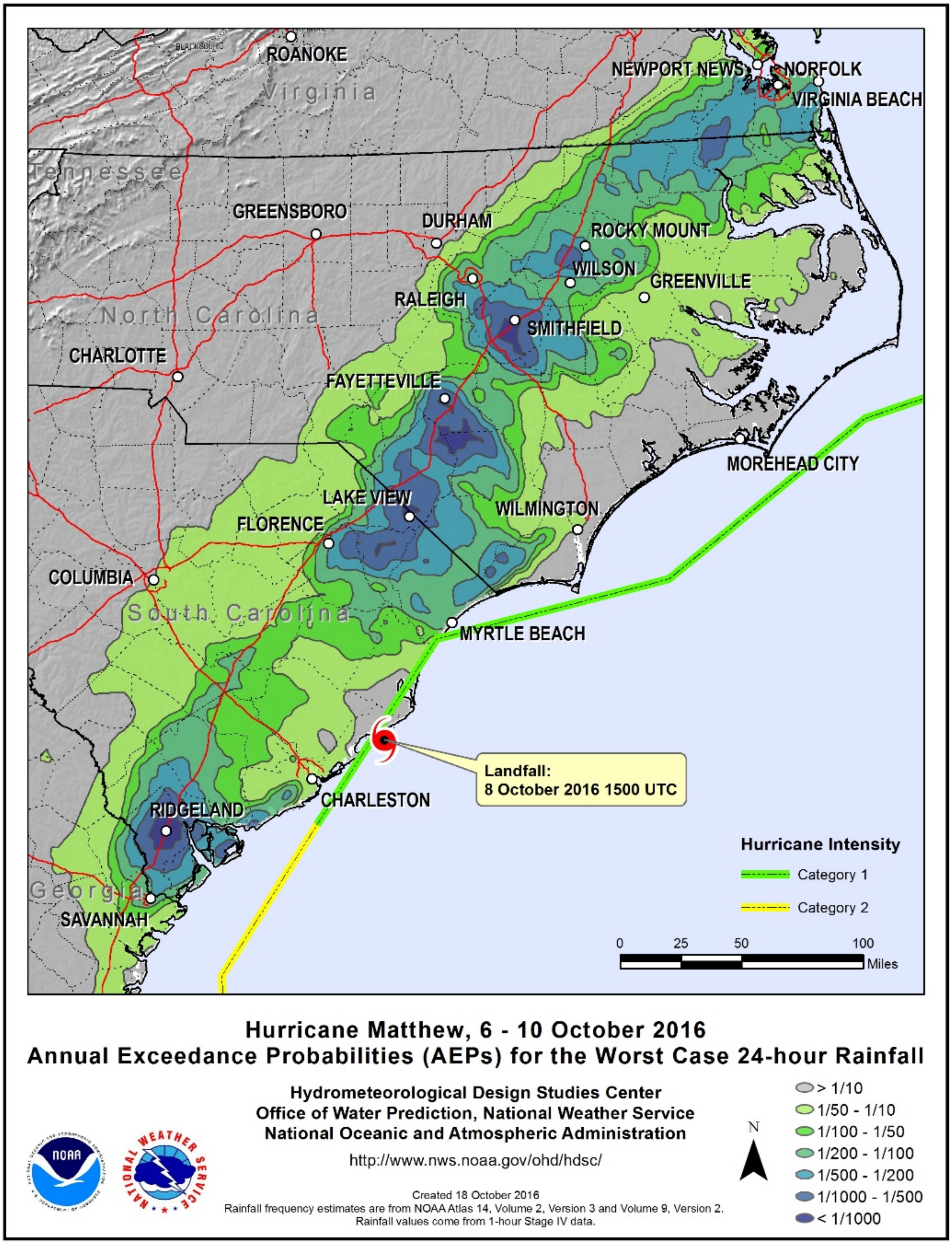

Figure 7. Annual exceedance probabilities for the worst case 24-hour rainfall between October 6 and 12, 2016 for Hurricane Matthew.