HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 July to 30 September 2018

Office of Water Prediction

National Weather Service

National Oceanic and Atmospheric Administration

U.S. Department of Commerce

Silver Spring, Maryland

October 2018

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) 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, accompanied by additional relevant information, are published as NOAA Atlas 14 and 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, precipitation frequency estimates have been updated for AZ, NV, NM, UT (Volume 1, 2004), DC, DE, IL, IN, KY, MD, NC, NJ, OH, PA, SC, TN, VA, WV (Volume 2, 2004), PR and U.S. Virgin Islands (Volume 3, 2006), HI (Volume 4, 2009), Selected Pacific Islands (Volume 5, 2009), CA (Volume 6, 2011), AK (Volume 7, 2011), CO, IA, KS, MI, MN, MO, ND, NE, OK, SD, WI (Volume 8, 2013), AL, AR, FL, GA, LA, MS (Volume 9, 2013), CT, MA, ME, NH, NY, RI, VT (Volume 10, 2015), and TX (Volume 11, 2018). OWP has been working with the Federal Highway Administration and several Northwestern state agencies on securing funding to extend NOAA Atlas 14 coverage to the remaining five northwestern states: ID, MT, OR, WA, WY in Volume 12. For any inquiries regarding the status of this effort, please send an email to HDSC.questions@noaa.gov.

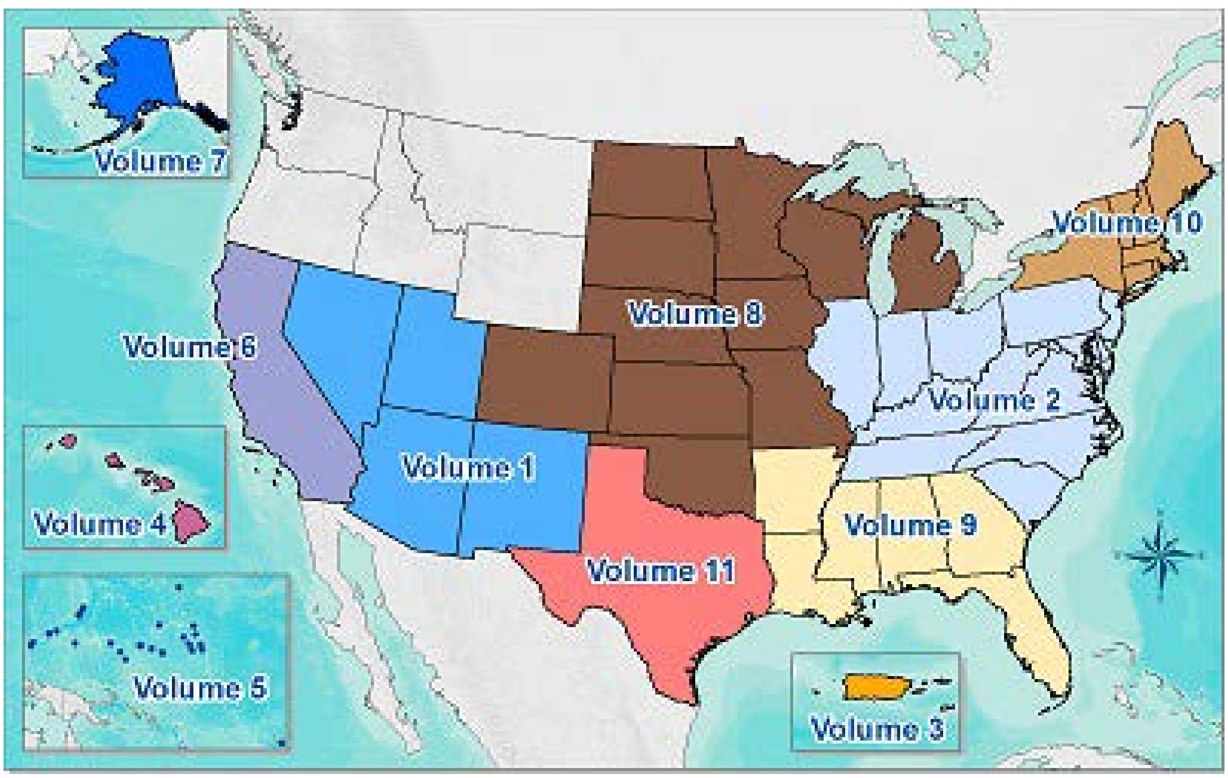

Figure 1. States or territories associated with each of the Volumes of the Atlas.

II. CURRENT PROJECTS

1. NOAA ATLAS 14 VOLUME 10: NORTHEASTERN STATES

Precipitation frequency estimates for the following seven northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont were published in September 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 PFDS. Work on documentation, which was put on hold in 2015 due to funding issues, restarted during this reporting period. Our estimate for the release of the NOAA Atlas 14 Volume 10 document is late December 2018.

2. NOAA ATLAS 14 VOLUME 11: TEXAS

2.1 PROGRESS IN THIS REPORTING PERIOD (JUL - SEP 2018)

Precipitation frequency estimates for Texas with supplementary products (except documentation) were published as NOAA Atlas 14 Volume 11 on 27 September 2018. Work on documentation describing the station metadata, data used in the analysis, and project methodology is currently in progress. Our estimate for the release of the NOAA Atlas 14 Volume 11 document is late December 2018.

All NOAA Atlas 14 Volume 11 products are available for download from the PFDS page for Texas, shown in Figure 2. Section 5 of the NOAA Atlas 14 documentation provides additional information on the underlying data and functioning of the PFDS.

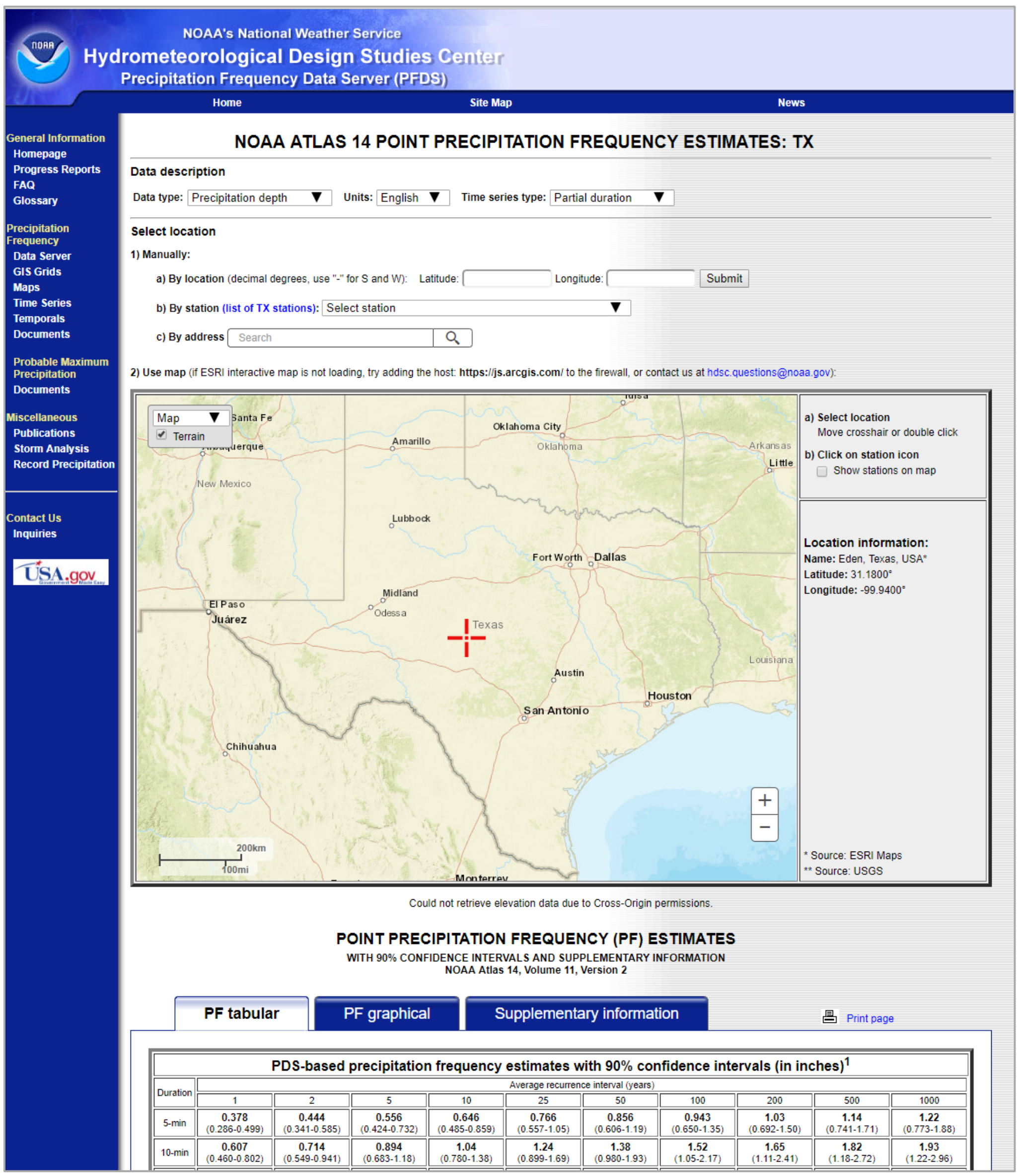

Figure 2. PFDS page for Texas.

When information is needed only for a specific location, it can be retrieved manually by entering the location's address or coordinates in decimal degrees (negative numbers should be entered for longitudes). It can also be retrieved from the map by dragging the red cursor on the map to the selected location or by double-clicking anywhere on the map. For gaged locations, a selection can also be made by choosing a station name from a pull-down list or clicking on an observing station on the map (after selecting "Show stations on map" and zooming in).

From the menu at the top of the page, a user can request partial duration series (PDS)-based or annual maximum series (AMS)-based precipitation frequency (PF) estimates to be displayed as precipitation depths or intensities in English or SI (metric) units. By default, PDS-based precipitation frequency depths in English units are shown. After a location is selected, all precipitation frequency and confidence limit estimates are displayed directly below the map in three separate tabs: "PF tabular" (displayed by default), "PF graphical" and "Supplementary information."

The side menu under the "Precipitation Frequency" tag is used to download various products applicable across the entire state, such as:

- GIS grids - ASCII grids of spatially interpolated PDS-based and AMS-based precipitation frequency estimates and accompanying bounds of a 90% confidence interval for durations from 5 minutes up to 60 days and for average recurrence intervals (ARIs) up to 1000 years can be downloaded via pull-down menu, via web browser, or by anonymous FTP. Grid metadata files, in Federal Geographic Data Committee compliant XML format, are automatically downloaded with corresponding grids.
- Maps - NOAA Atlas 14 cartographic maps of precipitation frequency estimates for selected ARIs and durations show contour lines created from gridded PDS-based precipitation frequency estimates for selected average recurrence intervals and durations. Figure 3 shows, as an example, isopluvials for 100-yr 24-hr estimates from Volume 11. Maps were created to serve as visual aids and are not recommended for interpolating estimates.
- Time Series - AMS data for Texas stations whose data were used in frequency analysis are published for consistency as constrained values, even if they captured true interval maximum amounts, so correction factors have to be applied to obtain unconstrained values. More information on conversion from constrained to unconstrained amounts across durations will be available from Section 4.5 of the NOAA Atlas 14 Volume 11 document.
- Temporals - Temporal distributions of precipitation amounts exceeding 2-yr estimates are provided for 6-hr, 12-hr, 24-hr, and 4-day durations for four temporal distribution regions delineated for Volume 11 project area (Figure 4). The temporal distributions for the duration are expressed in probability terms as cumulative percentages of precipitation totals. To provide detailed information on the varying temporal distributions, separate temporal distributions are also derived for four precipitation cases defined by the duration quartile in which the greatest percentage of the total precipitation occurred. More details on the derivation of temporal distribution curves will be provided in the Volume 11 document.

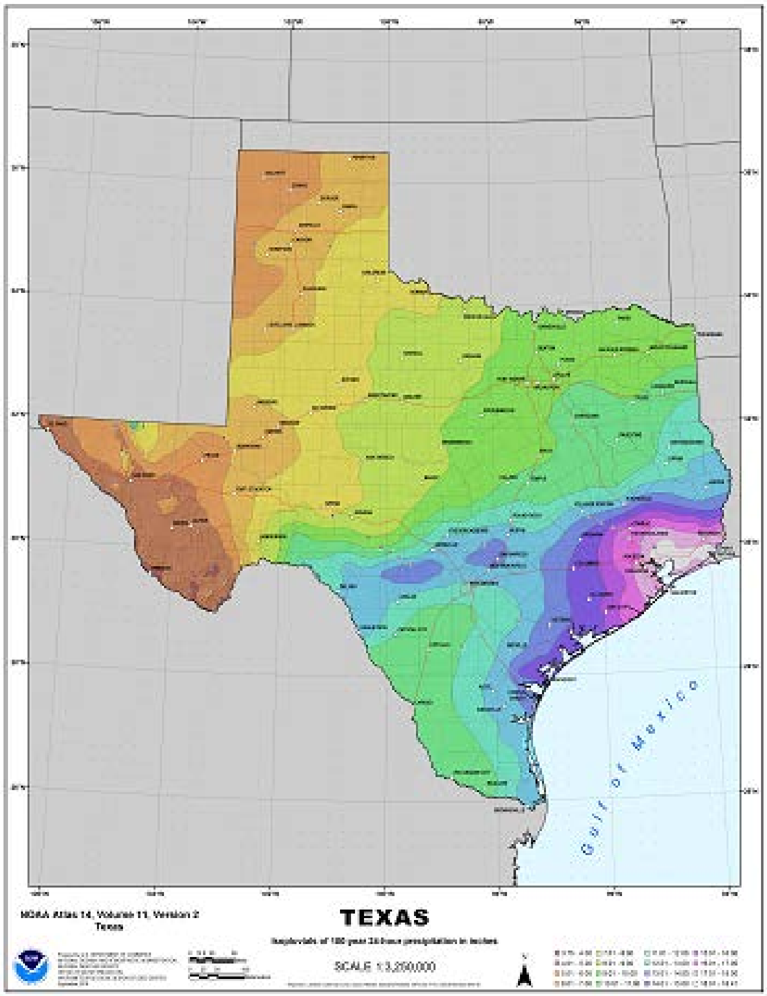

Figure 3. Isopluvials for 100-yr 24-hr estimates from Volume 11.

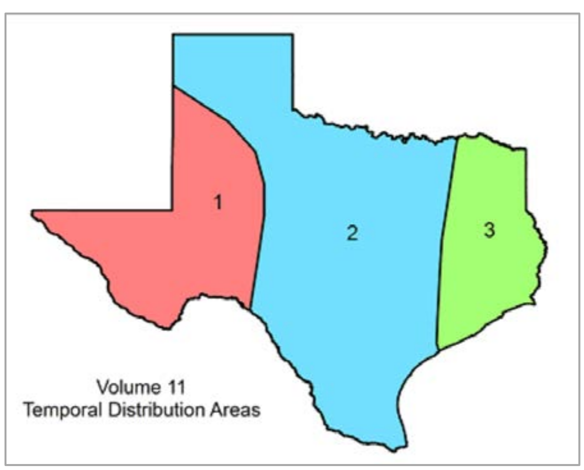

Figure 4. Temporal distribution areas for Volume 11.

2.2 PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (OCT - DEC 2018)

In the next reporting period, HDSC will prepare the NOAA Atlas 14 Volume 11 document with details on the data and processes used to derive Volume 11 products. The document will be published on the PF documents page.

2.3 PROJECT SCHEDULE

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

Extraction of annual maximum series; 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 the Volume 11 document [December 2018]

III. OTHER

1. ANALYSIS OF IMPACTS OF NON-STATIONARY CLIMATE ON NOAA ATLAS 14 PRECIPITATION FREQUENCY ESTIMATES

The current NOAA Atlas 14 method used to calculate precipitation depth-duration-frequency relationships assumes stationarity in the annual maximum series (AMS) data used for frequency distribution selection and fitting. Several at-station and regional parametric and non-parametric statistical tests are applied for each project area to detect trends in the AMS data. So far, none of the tests have shown geographically consistent trends (for more information, see, for example, the Volume 9 document).

Since 2016, HDSC has been working together with a team of scientists from the Penn State University on assessing the suitability of different non-stationary frequency analysis methods with respect to NOAA Atlas 14. All data analysis for this study was performed on daily and hourly precipitation data in the northeastern United States. Brief descriptions of the methods tested and a summary of the major findings are provided below; a detailed report on this work will be published on the PFDS website in late October 2018.

The study investigated partial duration series (PDS)-based modeling approach as an alternative to AMS-based modeling of extreme precipitation. PDS approaches are capable of making more efficient use of data by considering more than a single observation per year. It addressed two common subtasks involved in PDS construction: (1) selection of a high threshold, exceedances of which approximately follow a generalized Pareto distribution (GPD); and (2) appropriately handling weak temporal dependence in the data, which can be broken by thinning dependent sequences ("declustering"). A number of threshold selection methods for PDS construction were applied; the 0.98 empirical quantile was a good threshold to daily and hourly data throughout the study region. Furthermore, the PDS analysis was insensitive to choices of declustering technique, so the simple choice of run-length declustering with a default run length of one day was considered adequate.

In addition, three different estimators, L-moments, maximum likelihood (MLE), and generalized maximum likelihood (GMLE) were compared for both AMS and PDS models and evaluated based on accuracy of average recurrence interval estimation. A simulation study was performed to demonstrate how these three estimators perform under varying sample sizes and shape parameters. All three estimators gave relatively similar fits for stationary models applied separately to each station in the study region. Because of its ability to account for non-stationarity and incorporate potentially informative covariates (e.g. mean annual precipitation, elevation) that may improve inference on the distribution of extreme precipitation, while also constraining the shape parameter of the Generalized Extreme Value (GEV) and GPD distributions, the GMLE is preferred over the current usage of the L-moments estimators in this context.

A collection of tests was used to detect temporal trends in (1) exceedance rates of a fixed, high threshold; (2) the distribution of PDS data; and (3) the distribution of AMS data. The tests for trends in extremes gave regionally more consistent results when likelihoods were locally weighted than when considered at each station separately. Tests, both for linear changes in the location parameter of the GEV distribution and rate of exceedances of a fixed high threshold, showed evidence for positive trends at the majority of stations in the study region.

Three spline models of increasing complexity were compared for both GEV and GPD models for accommodating non-stationarities in the distribution of extremes with: smoothly varying (1) location parameter; (2) location and scale parameters; and (3) location, scale, and shape parameters. The fitted return level estimates from models (1) and (2) captured the slightly increasing trends in the data. Due to the difficulty in estimating the shape parameter under relatively short historical records, it is advocated that the shape parameter be fixed in time rather than allow it to vary smoothly in time as in (3).

A local likelihood approach for inferring the distribution of extreme precipitation at both observed and unobserved locations by pooling spatial information from nearby rain gauge locations was presented for both AMS and PDS data. The local likelihood model is capable of accommodating additional covariates that may explain differences in the distribution of extreme precipitation. The fitted local likelihood models allow for the location and scale parameters of the GEV and GPD distributions to vary as a function of a covariate (e.g., mean annual precipitation), which is more easily inferred. Both the fitted GEV and GPD models showed similar spatial patterns. However, the GEV model exhibited greater variability in ARI estimates than the GPD model, most likely due to the smaller sample size inherent in AMS data series.

Finally, an illustration for how climate model information can be incorporated by allowing GEV and GPD parameters to depend on covariates in order to account for long-term temporal non-stationarity was also presented.

Work on testing the feasibility of incorporating future climate projections into precipitation frequency analysis will continue in collaboration with researchers from the University of Illinois at Urbana-Champaign and the University of Wisconsin-Madison.

2. FREQUENCY ANALYSIS OF HURRICANE FLORENCE

HDSC creates maps of annual exceedance probabilities (AEPs) for selected significant storm events for which observed precipitation amounts have AEP of 1/500 or less over a large area for at least one duration. 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 to analyze 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 represent isohyets within the whole event. The maps, occasionally accompanied with extra information about the storm, are available for download from the AEP Storm Analysis page.

During this reporting period, we analyzed data from Hurricane Florence, 13 - 18 September 2018. Hurricane Florence made landfall at approximately 11:15 UTC on 14 September 2018 as a Category 1 Hurricane. Due to its slow movement, Florence produced torrential rain for days over North and South Carolina. We looked at a range of durations and selected a 72-hour period to analyze. Areas that experienced the maximum 72-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the map in Figure 5. Precipitation frequency estimates from NOAA Atlas 14 Volume 2 were used in the analysis. The underlying observed rainfall data came from 1-hour Stage IV multi-sensor precipitation estimates.

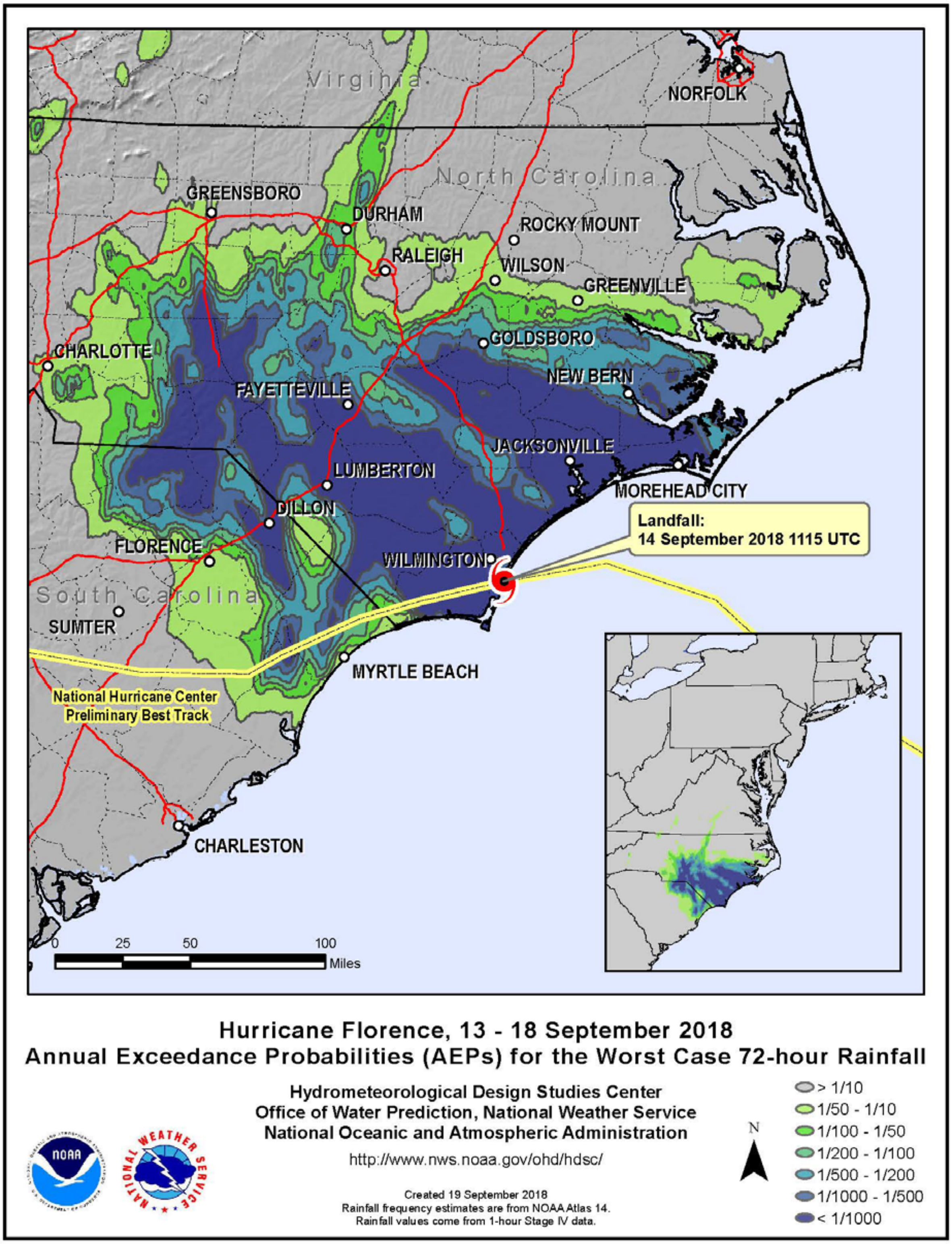

Figure 5. Frequency analysis for 72-hour rainfall from Hurricane Florence.