HYDROMETEOROLOGICAL DESIGN STUDIES CENTER

QUARTERLY PROGRESS REPORT

1 July to 30 September 2017

Office of Water Prediction
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 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 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 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), and CT, MA, ME, NH, NY, RI, VT (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. 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: 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.

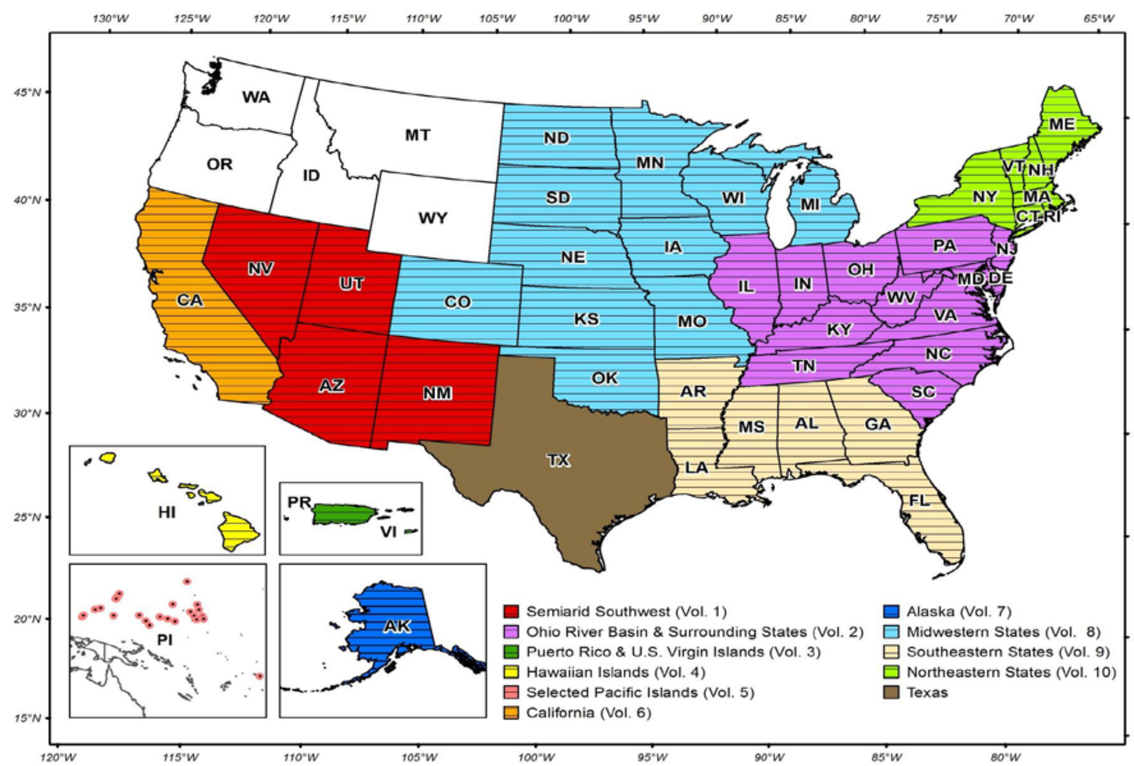

Figure 1. Current project area for Volume 11 (TX) and project areas included in published Volumes 1 to 10.

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 describing the station metadata, data, and project methodology was put on hold at the time until some funding issues are resolved. Present estimate for the publication of NOAA Atlas 14, Volume 10 document is March 2018.

2. NOAA ATLAS 14 VOLUME 11: TEXAS

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).

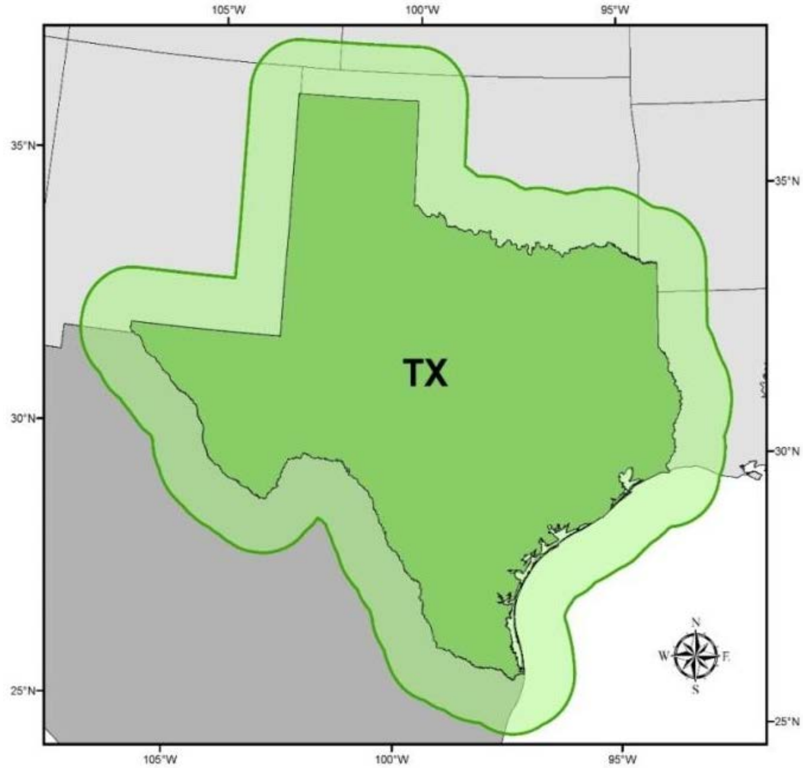

Figure 2. NOAA Atlas 14, Volume 11 extended project area.

The primary source of data for NOAA Atlas 14 Volumes is the NOAA's National Centers for Environmental Information (NCEI). In addition to the NCEI's data, we gathered precipitation data collected by other Federal, State and local agencies 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 and would like to thank all of those who responded to our inquiry and/or provided the data. We have formatted data for 11,931 stations from 34 datasets listed in Table 1. Each formatted station was assigned a unique 6-digit identification number (ID), where the first 2 digits of the ID indicate the dataset. Stations were then screened for duplicate records, potential merges and for sufficient number of years with usable data. Stations with shorter or less reliable records in station dense areas were removed from the database. After all the screenings, 3900 stations were retained for frequency analysis.

Table 1. List of formatted datasets.

Source of data: dataset/network name	ID (first 2 digits)	Recording period
NCEI: Automated Surface Observing System (ASOS)	78	1-min
NCEI: DSI 3260	03,05,14,16, 29,34,41	15-min
NCEI: DSI 3240	03,05,14,16, 29,34,41	1-hr
NCEI: Global Historical Climatology Network (GHCN)	03,05,14,16,29, 34,41,69,79,90	1-day
NCEI: Integrated Surface Data (Lite)	64	1-hr, 1-day
NCEI: Quality Controlled Local Climatological Data (QCLCD)	56	1-hr
NCEI: Unedited Local Climatological Data (ULCD)	55	1-hr
City of Austin ALERT Network	65	varying
City of Dallas ALERT Network	81	varying
Edwards Aquifer Authority	62	1-hr
Guadalupe-Blanco River Authority	77	6-min
Harris County Flood Control District's Flood Warning System	60	varying
Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network	82	varying
Lower Colorado River Authority Regional Meteorological Network	63	varying
Midwestern Regional Climate Center: CDMP 19th Century Forts and Voluntary Observers Database	52	1-day
National Atmospheric Deposition Program (NADP)	54	1-day
National Estuarine Research Reserve System (NERRS)	57	15-min, 1-hr
NWS Hydrometeorological Automated Data System	85	1-hr
Oklahoma Mesonet Observation Network	86	5-min, 1-day
San Antonio River Authority	91	varying
Sabine River Authority Precipitation Dataset	58	1-day
Servicio Meteorologico Nacional, Mexico	61	1-day
Tarrant Regional Water District (Greater Fort Worth area)/Tarrant County Urban Flood Control Network	83	15-min, 1-hr
Texas Commission on Env. Quality: Air Quality Network	75	1-hr
Texas Evapotranspiration Network	89	1-hr, 1-day
Texas Water Development Board (TWDB)	84	1-hr, 1-day
Titus County Fresh Water Supply District No. 1	53	1-day
U.S. Bureau of Reclamation: HydroMet	87	1-hr, 1-day
US Dept. of Agriculture (USDA): Agricultural Research Service (ARS)	94	varying
USDA, Forest Service: Remote Automated Weather Station (RAWS) Network	76	1-hr
USDA , National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	88	1-hr
USGS Nation Water Information System (NWIS)	59	15-min
USGS Hydrologic Data for Urban Studies in Texas	66	1-day
West Texas Mesonet	80	1-min, 15-min

2.1 PROGRESS IN THIS REPORTING PERIOD (Jul - Sep 2017)

During this reporting period we added Hurricane Harvey data, interpolated mean annual maximum (MAM) estimates to 30-arcsec resolution grid, and inspected spatial patterns in gridded MAM estimates. We completed the regionalization task and at-station frequency analysis and created depth-duration-frequency (DDF) curves at gauged locations. We also developed an initial set of gridded precipitation frequency estimates for 1-hour, 6-hour, 24-hour and 10-day durations. Finally, we worked on a development of the peer review web page that will be used for an external peer review of Version 1 estimates that will occur during the next reporting period.

The individual sections below describe in more detail the major tasks performed during this quarter.

2.1.1. Hurricane Harvey data

The precipitation frequency analysis approach used in NOAA Atlas 14 is based on analysis of Annual Maximum Series (AMS). For each station and duration, AMS is obtained by extracting the highest precipitation amount in each successive year. In order to incorporate the most recent information in the analysis, we periodically update the data during the duration of the project. During the latest update in mid-2017, data was extended up to December 2016, where available. In light of the extreme rainfall associated with Hurricane Harvey in August 2017, we manually added observed rainfall and extracted annual maxima for 2017 for a number of stations from the following datasets/networks: GHCN (Cooperative Observer Network and CoCoRaHS stations), ASOS, Harris County Flood Control District's Flood Warning System, Jefferson County Drainage District 6 ALERT Precipitation and Stream Level Network, Lower Colorado River Authority Regional Meteorological Network, and RAWS.

2.1.2. Spatial interpolation and analysis of mean annual maximum (MAM) data

Spatial interpolation of MAM values estimated at gauged locations is done by the Oregon State University's PRISM Climate Group using their hybrid statistical-geographic approach for mapping climate data. During this reporting period, two additional iterations were done with the PRISM group to ensure realistic spatial patterns and consistency in gridded MAMs for 1-hour, 6-hour, 1-day and 10-day durations. In the process, we reviewed MAM data for each station for inconsistencies relative to MAMs at nearby stations in order to identify locations where MAMs are affected by short periods of record or missed extreme amounts. Flagged MAMs were investigated and either adjusted or removed from the analysis.

2.1.3. Regionalization and development of Depth-Duration-Frequency (DDF) curves for gauged locations

During this reporting period, we finalized the regionalization task. In recent NOAA Atlas 14 Volumes, we used the region of influence regional frequency analysis approach where each station is assigned its own region with a potentially unique combination of nearby stations. For this project area, regions were defined based on stations' distances from a target station, elevation differences, inspection of their locations with respect to mountain ridges or the Gulf of

Mexico, and assessment of similarities/dissimilarities in the progression of relevant statistics across durations. During this process, some inconsistent stations were removed from the analysis, particularly in dense network areas where nearby stations have much longer records.

Depth-duration-frequency curves were then computed for all gauged locations using a regional frequency analysis approach based on Generalized Extreme Value distribution parameterized via L-moment statistics.

2.1.4. Development of gridded precipitation frequency estimates and analysis of spatial patterns in 2-year and 100-year gridded estimates

In NOAA Atlas 14, the interpolated MAM grids together with at-station precipitation frequency estimates are the basis for calculation of gridded precipitation frequency estimates and corresponding upper and lower bounds of the 90% confidence interval. For a selected duration, development of precipitation frequency grids utilizes the inherently strong (zero-intercept) linear relationship that exists between consecutive precipitation frequency estimates, as well as between 2-year precipitation frequency estimates and MAM.

During this reporting period, we developed gridded precipitation frequency estimates for durations between 1-hour and 10-days and for up to 100-year average recurrence intervals (ARIs). Presently, we are reviewing maps of the resulting estimates for the 2-year and 100-year ARIs. Inconsistent estimates or unreasonable patterns are resolved on a case-by-case basis in various ways: by manually adjusting the value to reflect expected patterns, omitting the station from the analysis, or by adding anchoring estimates at critical ungauged locations.

2.1.5. Development of a web page for the peer review

All NOAA Atlas 14 Volumes are subject to peer review which provides critical feedback on the reasonableness of DDF curves and spatial patterns in interpolated precipitation frequency estimates across durations and frequencies, and accuracy of station metadata. In mid-November, we will send out an invitation for a review of preliminary estimates to potential reviewers suggested by funding agencies as well as subscribers to our list server. All information needed for the review will be provided via a web page that is currently being constructed specifically for that purpose.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Oct - Dec 2017)

In the next reporting period, the peer review of Version 1 precipitation frequency estimates will occur. We will start addressing comments received from reviewers. The (anonymous) reviewers' comments with our responses and resulting actions will be published as Appendix 4 in the Volume 11 document. Additionally, we will work on the temporal distribution analysis and seasonality analysis tasks and will calculate scaling factors that will be used in assessment of 5-min and 10-min durations.

2.3. PROJECT SCHEDULE

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

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) [Done]

Regionalization and frequency analysis [Done]

Spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [In progress; October 2017]

Peer review [~~October 2017;~~ revised to November 2017]

Revision of PF estimates [~~January 2018;~~ revised to February 2018]

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

Web publication of data [May 2018]

Web publication of documentation [June 2018]

3. ANALYSIS OF IMPACTS OF NON-STATIONARY CLIMATE ON PRECIPITATION FREQUENCY ESTIMATES

The current NOAA Atlas 14 frequency analysis methods are based on the assumption of stationary climate in both historic and future precipitation records. As such, they may not be suitable for frequency analysis in the presence of non-stationary climate conditions.

In 2015, the Federal Highway Administration (FHWA) tasked HDSC to conduct a pilot project to analyze the impacts of the stationarity assumption on NOAA Atlas 14 estimates. For the pilot project, we reviewed relevant literature, selected frequency analysis methods suitable for distribution fitting under non-stationary conditions, and performed preliminary analyses. Our findings were inconclusive and the pilot project ended with more questions than answers.

We continue to look into this issue. Our objective is to develop a modeling framework that will allow non-stationary climate effects to be integrated into the NOAA Atlas 14 process, that will be applicable at a national scale and that will produce credible precipitation frequency estimates which can be relied upon by Federal water agencies. With that objective in mind, we identified four major tasks: (1) to identify the most suitable non-stationary precipitation frequency analysis methods from NOAA Atlas 14 perspective; (2) to test the feasibility of incorporating climate projections into precipitation frequency analysis and to design a method to express future climate information in a format that may be applicable for precipitation frequency analysis; (3) to implement and test selected deterministic and/or probabilistic non-stationary precipitation frequency analysis method(s) on a designated project area to derive precipitation frequency estimates using historical data and/or historical data coupled with future precipitation data derived from downscaled climate projections; (4) to assess the added value of new precipitation frequency estimates with respect to traditional NOAA Atlas 14 estimates and to recommend an approach that will be appropriate for national implementation.

Together with Penn State University team, led by Drs. Shaby and Mejia, we have been working on assessing the suitability of selected deterministic non-stationary frequency analysis methods with respect to NOAA Atlas 14 (Task 1) and testing them on NOAA Atlas 14 Volume 10 project area (as part of Task 3). The work on both tasks is well on its way and we expect to publish a report on major findings on deterministic methods (without inclusion of downscaled climate projections) by mid-2018. During this reporting period, we continued evaluation of DDFs from various types of non-stationary models against the current NOAA Atlas 14 stationary model. We have also been investigating a number of related issues, such as, performance of the AMS and Partial Duration Series (PDS) models in terms of the uncertainty of precipitation frequency estimators, effects of different de-clustering techniques and threshold selection mechanisms for the PDS model, effects of different distribution parameterization techniques. In the next reporting period, we will continue those investigations and start development of regional non-stationary frequency analysis methods. We are also considering exploring if other covariates (e.g., ENSO, NAO) in addition to time may improve estimates.

We also plan to team up with the University of Illinois, Urbana-Champaign research team lead by Drs Markus, Angel and McConkey for Task 2): testing the feasibility of incorporating climate projections in precipitation frequency analysis. The proposal for this work, "Updating Precipitation Frequency Estimates under Non-Stationary Climate Conditions Using Projected Climate Data" is currently under review by the NOAA contract office. We expect that work on Task 2 will start in January 2018.

III. OTHER

1. FREQUENCY ANALYSIS OF RECENT HISTORICAL STORM EVENTS

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, 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 12-hour rainfall during the Hurricane Maria in September 2017. The analysis of Hurricane Harvey was postponed until we develop preliminary precipitation frequency estimates for Texas.

1.1. HURRICANE MARIA, SEPTEMBER 2017

Hurricane Maria made landfall in Puerto Rico around 1015 UTC on September 20th near Yabucoa, a city along the island’s southeastern coast. Maria was the first Category 4 storm to make landfall on the island in more than 80 years.

We analyzed AEPs for this event for several durations and decided to create an AEP map for the 12-hour period. Areas that experienced the maximum 12-hour rainfall magnitudes with AEPs ranging from 1/10 (10%) to smaller than 1/1000 (0.1%) are shown on the map in Figure 3. Precipitation frequency estimates used in the analysis were from the NOAA Atlas 14 Volume 3. The underlying observed data came from the he NCEI's multi-sensor Stage IV QPE Product. Since the hurricane demolished the main weather radar, the Stage IV estimates were mostly driven by rain gauge observations available on September 21st, when the map was created.

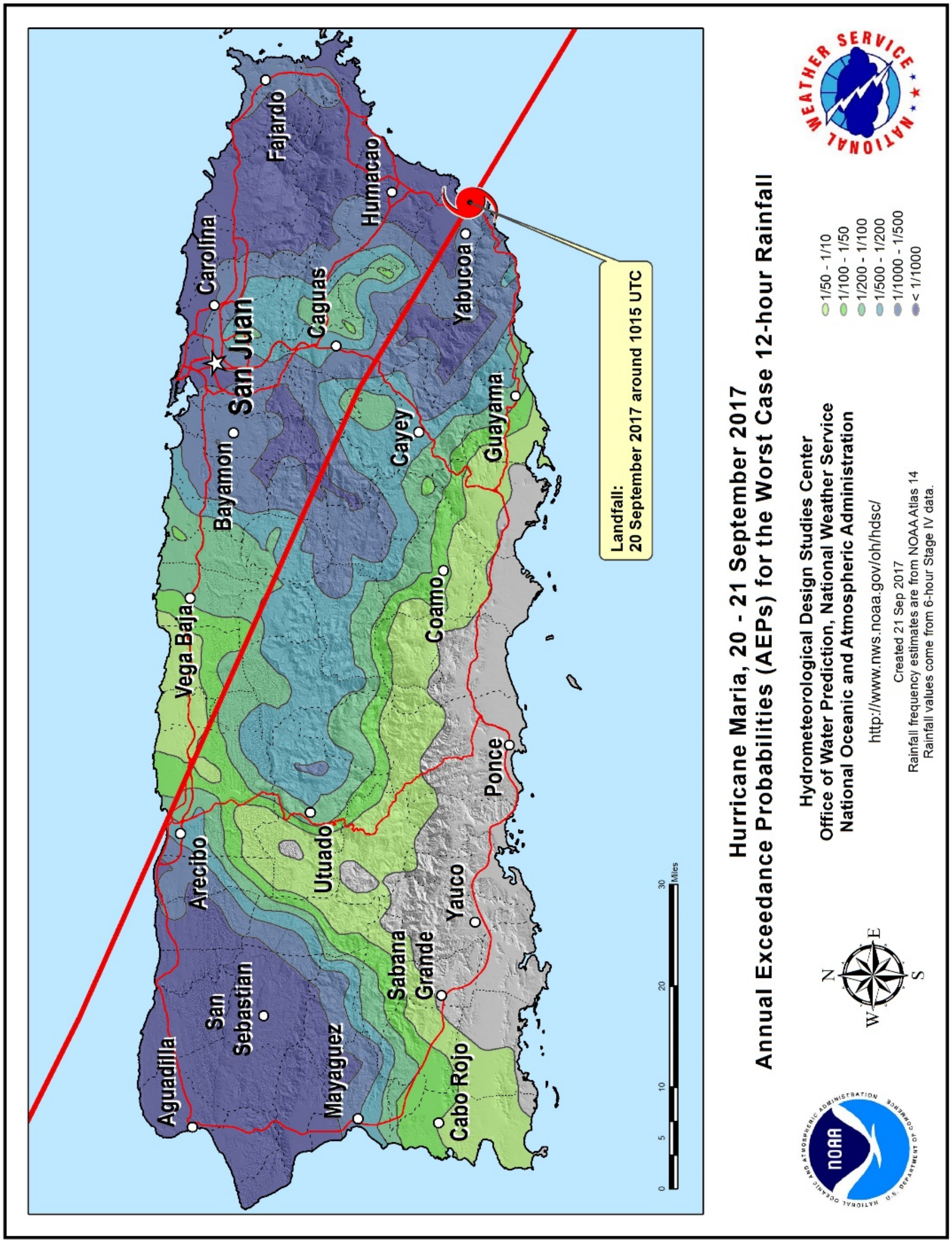

Figure 3. Annual exceedance probabilities for the worst case 12-hour rainfall during Hurricane Maria over Puerto Rico.

1.2. NOTE ON HURRICANE HARVEY

The analysis for Hurricane Harvey was postponed until we develop preliminary precipitation frequency estimates for NOAA Atlas Volume 11: Texas. If we were to do the analysis at this time, it would be based on estimates from the Technical Paper No. 40 - TP40 (1961) that have the potential to change dramatically in the Houston area for the following reasons: a) there have been several significant events in the Houston area since TP40 publication; b) data records are extended by over 50 years for NOAA Atlas 14, making statistical analysis more reliable; c) significantly more gauges, including local datasets like the Harris County Flood Control District dataset, are available for NOAA Atlas 14 and that will improve spatial patterns. Also, we expect to see observed precipitation amounts across many durations to have annual exceedance probabilities of 1/500 (corresponding to 500-yr average recurrence interval) or less over large areas. If we were to use TP40 we would have to extrapolate estimates beyond 100-years, making assessment unreliable.