HYDROMETEOROLOGICAL DESIGN STUDIES CENTER QUARTERLY PROGRESS REPORT

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Office of Hydrologic Development

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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. The Atlas is divided into volumes based on geographic sections of the country and affiliated territories. NOAA Atlas 14 is a web-based document available through the Precipitation Frequency Data Server (PFDS; http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

HDSC is currently updating estimates for 24 U.S. states. Estimates for the following midwestern states: Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin; and the following southeastern states: Alabama, Arkansas, Georgia, Florida, Louisiana and Mississippi will be published in 2013 as Volumes 8 and 9, respectively. Estimates for the following northeastern states: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont will be published in 2015 as Volume 10. Figure 1 shows new project areas as well as updated project areas included in NOAA Atlas 14, Volumes 1 to 7.

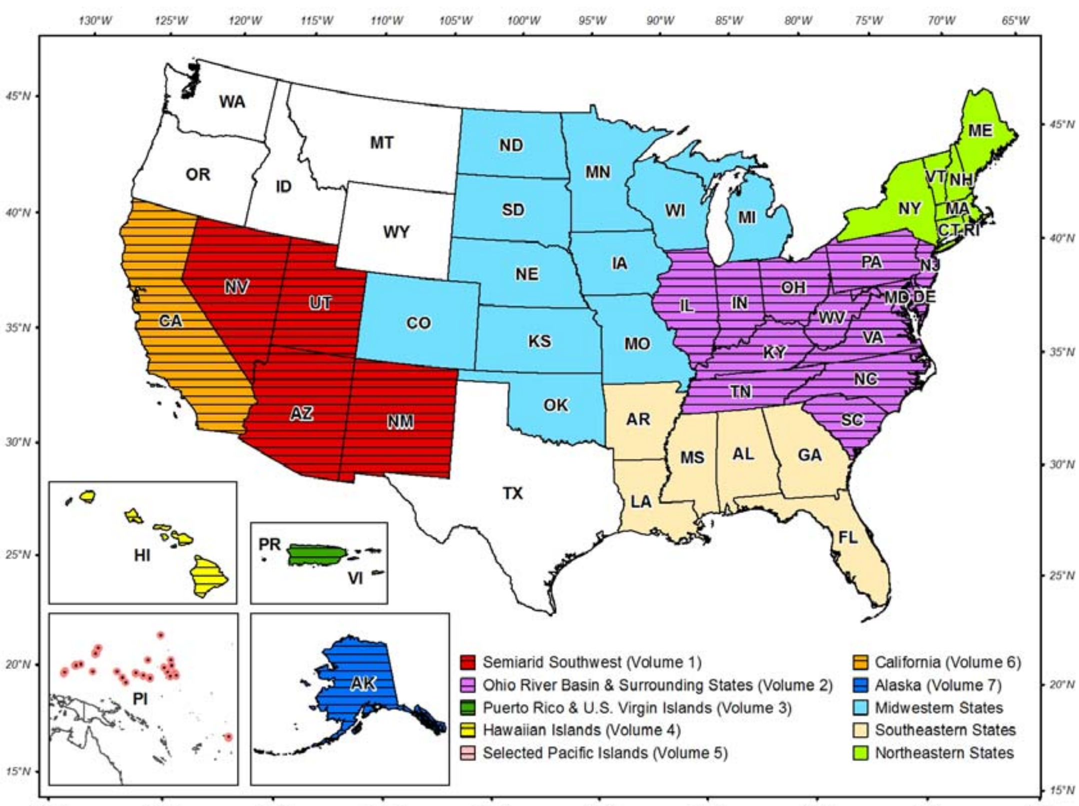

Figure 1. Current project areas and project areas included in published NOAA Atlas 14, Volumes 1-7.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECTS FOR THE MIDWESTERN AND SOUTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2012)

To facilitate a more efficient process, the Midwestern and Southeastern precipitation frequency projects are being done simultaneously. Because of that, the results shown in this section apply for both projects. Both project areas are shown in Figure 2.

The Midwestern project area includes the states of Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin and an approximately 1-degree buffer around these core states.

The Southeastern project includes the states of Alabama, Arkansas, Florida, Georgia, Louisiana and Mississippi and an approximately 1-degree buffer around these core states.

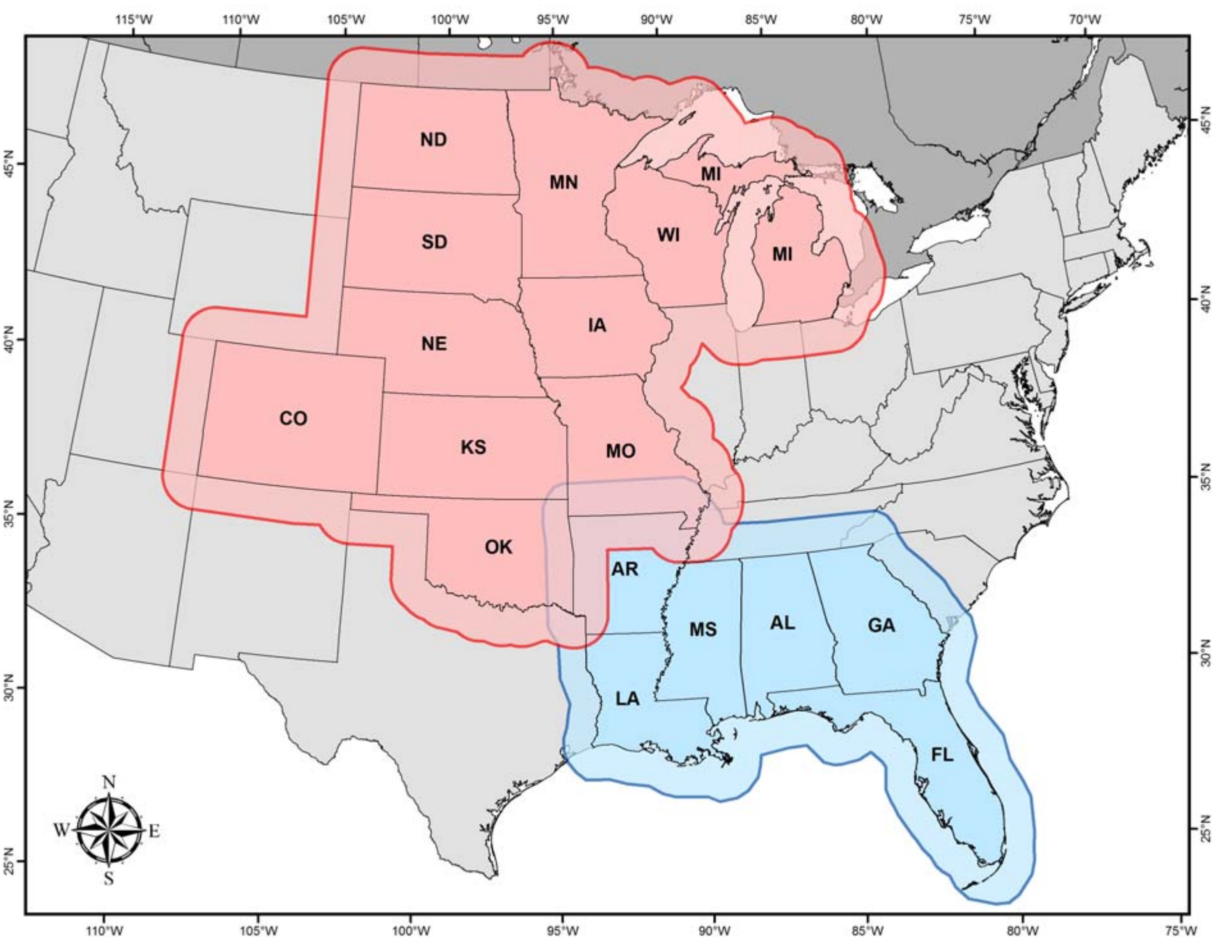

Figure 2. Midwestern precipitation frequency project areas (red) and Southeastern precipitation frequency project area (blue).

1.1.1. Peer review process

HDSC conducted a peer review of preliminary precipitation frequency estimates for the midwestern states (NOAA Atlas 14, Volume 8) and southeastern states (NOAA Atlas 14, Volume 9) from October 11th to November 16th. The request for review was sent via email to the over 750 subscribers to the HDSC list-server as well as other interested parties. Potential reviewers were asked to evaluate the accuracy of station metadata and the reasonableness of point precipitation frequency estimates in addition to their spatial patterns. Specifically, the review covered:

- Station metadata
  - *Metadata for stations whose data were used to prepare mean annual maximum precipitation maps and/or precipitation frequency estimates*. The list included information on station name, state, source of data, assigned station ID, latitude, longitude, elevation, and period of record. It also showed 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 contained basic metadata for stations that were not used and the reason why (e.g., because there was another station with a longer period of record nearby, 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);
- At-station depth-duration-frequency (DDF) curves
  - *DDF curves for stations used in analysis for durations between 1-hour and 10-days and for average recurrence intervals from 2-year through 100-year*;
- Cartographic maps
  - *Maps of spatially-interpolated mean annual maxima for 60-minute, 24-hour and 10-day durations;*
  - *Maps of spatially-interpolated 2-year and 100-year precipitation frequency estimates for 60-minute, 24-hour and 10-day duration.*

We received comments from at least 46 individuals representing, among others, the U.S. Army Corps of Engineers, United States Geological Survey, and several State Climatology Offices, Water Management Districts and Weather Forecast Offices. No feedback was received regarding estimates in the following states: Alabama, Arkansas, Georgia, Iowa, Louisiana, and Mississippi. Therefore, effort was made to reach out to additional contacts for those areas.

1.1.2. Revision of station data and estimates in response to peer review

a. Station metadata and data

We addressed reviewer comments pertaining to station metadata and data records first. The work led to 26 station location adjustments and nine additional station merges to create longer records.

During the peer review process, we obtained 15-minute data for an additional 24 stations in Michigan from the Oakland County Water Resources Commissioner. We quality controlled the data and extracted annual maximum series across durations. These data will be primarily used to extend the records of Southeast Michigan Council of Governments (SEMCOG) hourly stations, which were previously deleted due to short records.

b. At-station mean annual maximum estimates

Many reviewers commented on the predominance of station-driven contour lines (e.g., bulls' eyes) in the mean annual maxima (MAM) cartographic maps, especially in the 1-day duration. During this reporting period, we investigated causes and ways to mitigate this effect for the final grids. The majority of these artifacts were the result of small differences in estimates at nearby stations and selected mapping contour intervals; the rest were primarily due to inconsistencies in periods of record. Selected stations were examined and excluded from the MAM values used for interpolation when their exclusion resulted in smoothed patterns and did not otherwise impact MAM interpolation, especially for sub-daily durations. Daily-only stations (i.e., stations that had no co-located hourly data) with less than 50 years of data in flat terrain have been excluded. In addition, we reviewed co-located daily and hourly stations with less than 50 years of daily data; 57 of them were excluded on a case by case basis. All exclusions were pertinent only to the MAM interpolation; stations were still retained for frequency analysis.

We estimated hourly MAMs for three crucial daily SNOTEL stations in Colorado to anchor and improve hourly MAM interpolation at higher elevations.

Lastly, in response to reviewer comments, the station-dense area around St. Paul-Minneapolis in Minnesota was revisited. Many stations there sampled the same period and could be biasing the results. This analysis resulted in deletion of fourteen daily stations.

c. At-station precipitation frequency estimates

The regional frequency analysis approach used in NOAA Atlas 14 volumes utilizes data from nearby stations that are expected to have similar frequency distributions as a station of interest to yield more accurate estimates of extreme quantiles. More details on the regionalization approach can be found elsewhere, for example in Section 4.6.2 of Volume 7 (http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume7.pdf).

After the peer review, station regions were revisited to accommodate the addition and deletion of stations and to investigate if different regions would improve the spatial smoothness and reliability of the precipitation frequency estimates, especially in areas where 100-year estimates did not conform to expected regional patterns. This regionalization effort is near completion.

Continual review of data quality led to the removal of additional low outliers affecting the annual maximum series distribution at some stations. During this effort, we identified and deleted thirteen stations as unreliable due to multiple questionable annual maxima extracted from years with incomplete records and relatively short periods of record.

d. Interpolation of mean annual maxima and precipitation frequency estimates

Mean annual maximum (MAM) grids serve as the basis for deriving gridded precipitation frequency estimates at different frequencies and durations. Oregon State University's PRISM Climate Group developed the MAM grids from at-station MAM values using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM). At the request of HDSC, the PRISM Climate Group created several versions of MAM grids by varying the parameters of a dynamic filter that controls the smoothing of the grids as a function of estimate variability in a given area.

After HDSC reviewed differences in resulting MAM patterns from various iterations, a decision was made to have the PRISM Climate Group retain the same filter parameters that were used for the peer reviewed MAMs.

As an alternative to changing the PRISM filter, HDSC developed a method that applies a dynamic filter to 2-year grids calculated from MAM grids. Parameters of the filter, which control the amount of smoothing, are a function of elevation gradients and proximity to the coastline. Parameters were selected such that maximum smoothing is applied in flat terrain, no smoothing is applied in the mountains, and the transition from one to another is gradual. The resulting smoothed grids will then serve as the basis for the derivation of grids for all other recurrence intervals.

1.1.3. Longer duration precipitation frequency estimates for Missouri

At the request of and with the funding provided by the Missouri Department of Natural Resources, HDSC is also developing precipitation frequency estimates for average recurrence intervals through 10-years for the state of Missouri for the 90-day, 180-day, and 365-day durations. During this reporting period, HDSC derived initial MAM grids for those three durations using multiple linear regression techniques with 60-day MAM grids, latitude and longitude. We are currently analyzing resulting spatial patterns. Once the MAM grids are finalized, we will develop the precipitation frequency grids using a similar approach as for durations 1-day through 60-day.

1.1.4. Precipitation frequency estimates for n-minute durations

To develop precipitation frequency estimates for durations shorter than 60-minutes, we investigated ratios of 15- and 30-minute MAMs to 60-minute MAMs. Spatial patterns were observed in the ratios; e.g., ratios were consistently higher in the Colorado mountains and the northern Midwestern states than in other areas. Ratios of 5-minute and 10-minute MAMs to 15-minute MAMs were pretty much uniform. Therefore, 15-minute and 30-minute ratios will be interpolated to grids to be applied to 60-minute grids and a single scaling factor applied to 15-minute grids will be used for 5-minute and 10-minute durations. The scaling factors were computed as an average of all 5-minute and 10-minute to 15-minute annual maxima ratios, respectively.

1.1.5. Trends in annual maximum series

The precipitation frequency analysis methods used are based on the assumption of a stationary climate over the period of observation. To test this assumption we conducted a trend analysis on the annual maximum series (AMS) data. First, we applied parametric and non-parametric tests for trends in mean. 1,850 daily stations with more than 70 years of data were tested for trends. To ensure consistency in results, tests were also performed on 1,590 daily stations that have data for a common time period from 1930 to 2010. In both cases, statistically significant trends were detected in fewer than 20% of stations. When plotted on a map, stations where tests detected positive or negative trends were scattered across the project area with no geographic consistency.

In addition, we used the Levene test to check for any trends in the variance of the AMS data. The investigation showed that less than 1% showed any trend in variance over time.

1.1.6. Comparison with previous NWS studies

With each volume of NOAA Atlas 14, we provide a comparison of the estimates against the previous NWS study. To facilitate the comparison, we digitized maps of the 2-year and 100-year recurrence intervals for the 1-hour and 1-day durations from Technical Paper 40. This will allow us to produce difference maps against the final estimates.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2013)

In the next reporting period, HDSC will complete the revision of precipitation frequency estimates and address all peer reviewer comments. Additionally, we will complete the following tasks: temporal distribution analysis, seasonality analysis and rainfall (as opposed to precipitation) frequency analysis. We will publish the final precipitation frequency estimates via the Precipitation Frequency Data Server in March.

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 [Complete]

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

Peer review [Complete]

Revision of PF estimates [November 2012; revised to January 2013]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [January 2013]

Web publication [March 2013]

2. PRECIPITATION FREQUENCY PROJECT FOR THE NORTHEASTERN STATES

2.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2012)

The project area includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont and an approximately 1-degree buffer around these states (Figure 3).

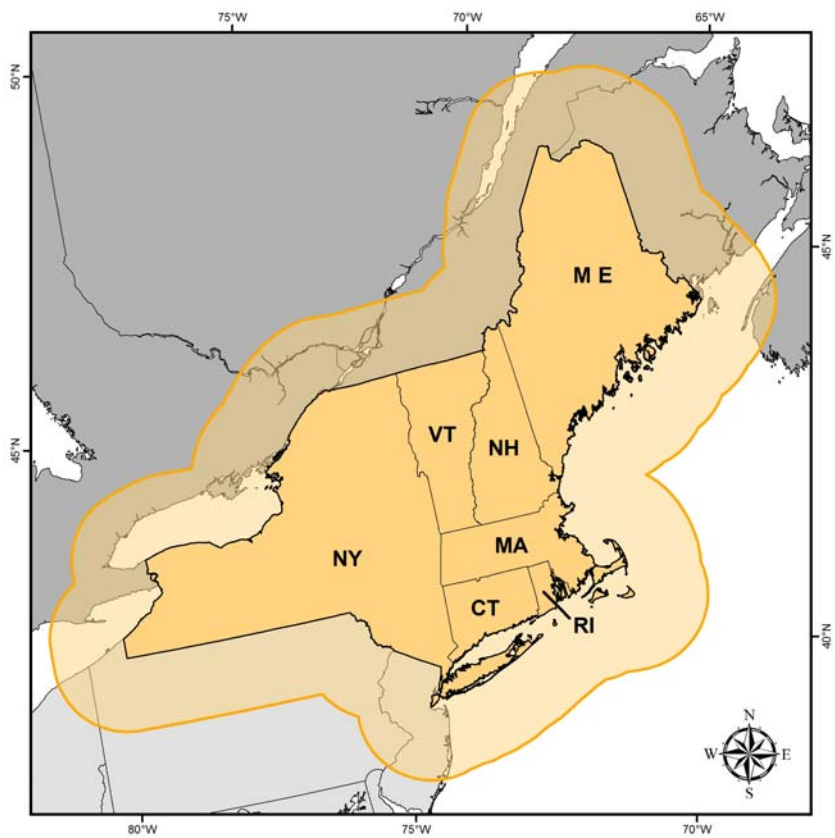

Figure 3. Northeastern precipitation frequency project area (shown in orange).

2.1.1. Data collection

The primary source of data is the National Climatic Data Center (NCDC), but digitized data measured at reporting intervals of 1-day or shorter are also being collected from known data sources. Table 1 shows the data collected thus far.

During this reporting period, we obtained 1-day and 1-hour data from Environment Canada. Additionally, data from all sources were organized, summarized, and prepared for formatting.

If you know about other data we could use, please contact us at HDSC.Questions@noaa.gov.

Table 1. Sources of data for the precipitation frequency analysis for the Northeast states. Datasets in grey were investigated but will not be used for various reasons.

Source	Reporting interval	Preliminary number of stations	Status
Automated Surface Observing Systems (ASOS)	1-minute	42	Downloaded from website.
Colorado Climate Center: Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)	1-day	TBD	Downloaded from FTP site.
Environment Canada	1-day 1-hour	TBD	Downloaded from FTP site.
Illinois State Water Survey: National Atmospheric Deposition Program (NADP) dataset	1-day	57	Downloaded from website.
Massachusetts Department of Conservation and Recreation (DCR)	1-day	176	Received on CD.
Mid-Atlantic River Forecast Center: Integrated Flood Observing and Warning System (IFLOWS) data	varies	TBD	Received on DVD.
Midwestern Region Climate Center (MRCC): 19th Century Forts and Voluntary Observers Database	1-day	63	Downloaded from FTP site.
National Climatic Data Center (NCDC)	1-day 1-hour 15-minute n-minute	3001 593 517 TBD	Downloaded (except n-min) from website.
National Environmental Satellite, Data, and Information Service (NESDIS): U.S. Climate Reference Network (USCRN)	1-day 1-hour	11 11	Downloaded from NCDC website.
National Resources Conservation Service (NRCS): Soil Climate Analysis Network (SCAN)	1-hour 1-day	6 6	Downloaded from website.
Rhode Island Department of Environmental Management, Office of Water Resources	1-hour	1	Received via email.
U.S. Department of Agriculture: Agricultural Research Service (ARS)	variable	23	Downloaded from website; working to ascertain station metadata.
U.S. Forest Service: Remote Automated Weather Stations (RAWS) dataset	1-hour	TBD	Currently downloading from FTP site.
U.S. Geological Survey (USGS) Connecticut Water Science Center	1-day; 15-minute	TBD	No progress.
USGS Maine Water Science Center	1-day 15-minute	16 n/a	Downloaded from website.
USGS Massachusetts-Rhode Island Water Science Center	1-day 15-minute	11 5	Downloaded from FTP site.
USGS New Hampshire-Vermont Water Science Center	1-day 15-minute	6 n/a	Downloaded from website.
USGS New York Water Science Center	1-day 15-minute	1 1	Received via email.
Global Summary of the Day (NCDC)	1-day	n/a	Data are duplicate of NCDC and Environment Canada data.
Northeast Regional Climate Center (NRCC): CLimate Information for Management and Operational Decisions (CLIMOD)	1-day	n/a	Data are duplicate of NCDC.
U.S. Army Corps of Engineers	1-hour	n/a	No suitable dataset available.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2013)

Data collection and formatting will continue. Quality control of the NCDC metadata will begin.

2.3. PROJECT SCHEDULE

Data collection, formatting, and initial quality control [June 2013]

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) [December 2013]

Regionalization and frequency analysis [July 2014]

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

Peer review [December 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]

3. AREAL REDUCTION FACTORS

3.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2012)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same recurrence interval for an area of interest. HDSC performed extensive literature review of ARF methods and their main advantages and disadvantages and selected three diverse fixed-area ARF methods for further evaluation. Selection was done primarily from the perspective of their potential application to NOAA Atlas 14 precipitation frequency estimates.

The first method uses spatial correlograms and extreme value theory principles to derive the ARFs. It is based on assumptions that the areal-averaged parent rainfall is gamma distributed and that the link between the point parent and areal parent rainfall is only dependent on the spatial correlation of rainfall. Since areal-averaged extreme value distribution of rainfall is calculated from the measured point parent rainfall, no spatial interpolation is needed to generate areal estimates.

The second 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. To estimate the parameters of the ARF equation, areal estimates are needed. They can be estimated either by interpolation of gauge data or by making use of radar estimates (or any other multisensor rainfall estimates in a gridded form). One potential disadvantage of this method is that derived ARFs do not depend on frequency.

For the third method, the point and areal intensity-duration-frequency curves are characterized using the Generalized Extreme Value (GEV) distribution. The parameters of the common GEV distribution are a function of both the area and duration. Similar to the second method, areal estimates obtained through interpolation of gauge data or from radar data are needed to obtain distribution parameters.

In addition, HDSC developed a new copula-based ARF method. This method uses copulas along with spatial dependence structure to model the distribution of the rain field over a catchment area. The model can also incorporate rainfall intermittency directly in the parent distribution. Areal estimates are then obtained from the joint distribution and these estimates are used in turn to obtain areal reduction factors.

Due to limited resources and higher priority precipitation frequency projects, during this reporting period, modest progress was made on comparing the four ARF methods using a test dataset in Oklahoma. Progress was made on two tasks:

(1) The copula-based approach is being extended for the AMS data obtained from the rain-gauge system. We investigated several spatial stationary correlation models (generalized exponential, power, Matern and Gaussian functions) and found that the generalized exponential gave the most reasonable fit to spatial correlograms. Fits were optimized using pre-determined significant distances.

(2) We studied the impacts of using different spatial interpolation approaches on gauge data and using radar data in the estimation of ARFs.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2013)

Limited activities are expected in the next reporting period to allow us to focus on precipitation frequency projects, especially to deliver the projects for the midwestern and southeastern states on schedule.

3.3. PROJECT SCHEDULE

It is expected that this project will be completed by the end of 2013.

III. OTHER

1. ONLINE PUBLICATIONS

We are still in the process of making previous publications from this office available on-line. This includes all Technical Papers, Technical Memoranda, Technical Reports, and Hydrometeorological Reports dating back to 1938. The majority of the documents are scanned and checked and will be available on the HDSC web page by the end of January.