HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
QUARTERLY PROGRESS REPORT

1 October 2011 to 31 December 2011

Office of Hydrologic Development

U.S. National Weather Service

National Oceanic and Atmospheric Administration

Silver Spring, Maryland

January 2012

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 Alaska, the following southeastern states: Alabama, Arkansas, Georgia, Florida, Louisiana and Mississippi, and the following midwestern states: Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin. The following northeastern states have signed up to update estimates through the Federal Highway Administration's (FHWA) Pooled Fund Program and we are waiting on actual fund transfers: Connecticut, Massachusetts, Maine, New Hampshire, New York, Rhode Island and Vermont. Once the Pooled Fund Program has received the funds from each State, contract documents between FHWA and NWS can be finalized, and we will begin the three year task of updating precipitation frequency estimates for the northeastern states. Figure 1 shows new project areas as well as updated project areas included in NOAA Atlas 14, Volumes 1 to 6.

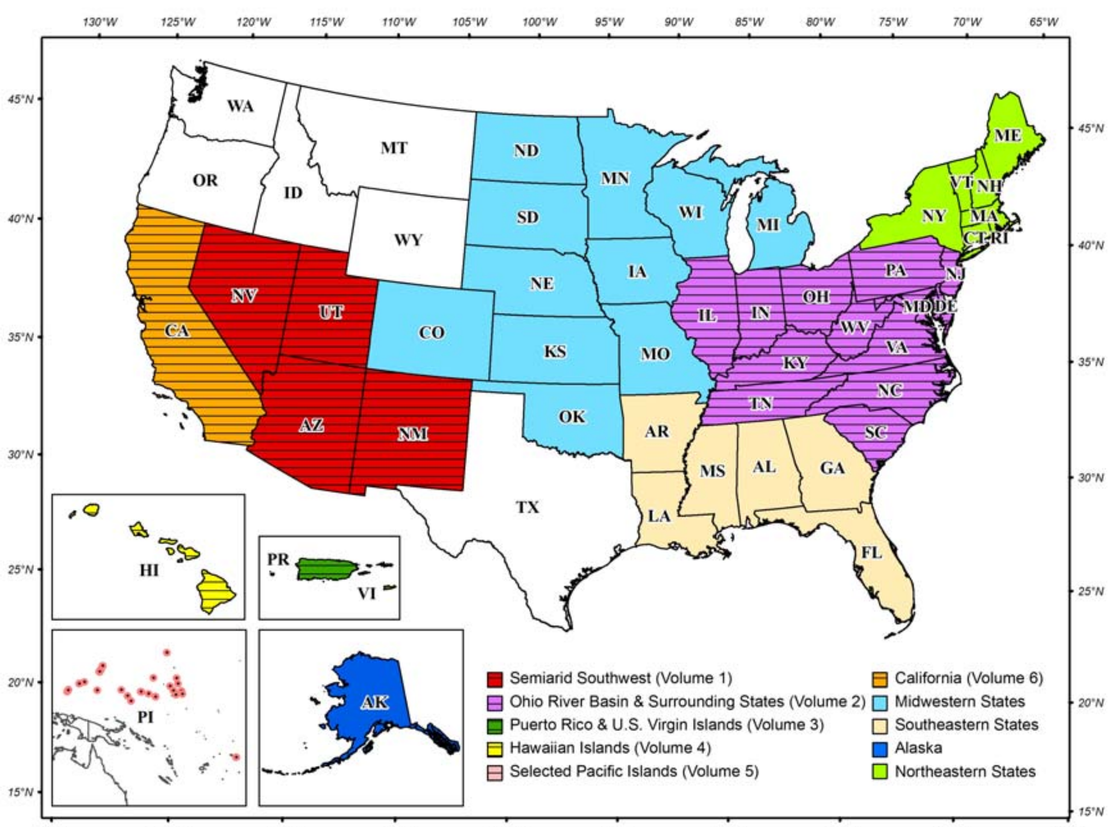

Figure 1. Current project areas and project areas included in published NOAA Atlas 14, Volumes 1-6.

II. CURRENT PROJECTS

1. PRECIPITATION FREQUENCY PROJECT FOR THE SOUTHEASTERN STATES

1.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2011)

The project includes the states of Alabama, Arkansas, Florida, Georgia, Louisiana and Mississippi and an approximately 1-degree buffer around these core states (Figure 2). To facilitate a more efficient process, Southeastern and Midwestern (see Section 2) precipitation frequency projects are being done simultaneously. Because of that, some of the results shown in this report apply for both projects.

Significant loss of HDSC personnel in recent months and a failure of the Office of Hydrologic Development's (OHD) computing storage cluster in December have impacted the progress of this project during this report period (see Section III for details).

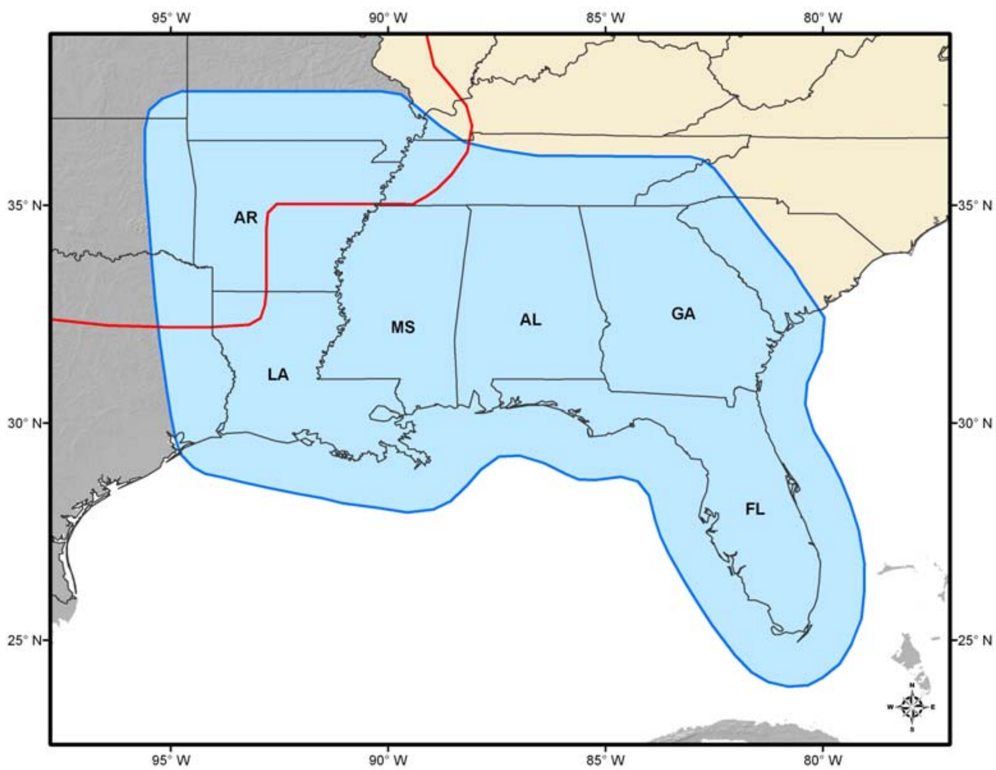

Figure 2. Southeastern precipitation frequency project area (shown in blue). Also shown is the border of the Midwestern precipitation frequency project area (red line).

1.1.1. Data collection and formatting

Existing 15-minute, hourly and daily stations were extended with newly released data from the National Climatic Data Center (NCDC). Data at 15-minute and hourly NCDC stations were extended through December 2010 and data at daily stations through October 2011.

Effort was made to confirm that all significant events recorded in various publications were included in our datasets. Among others, significant events from Monthly Weather Review's *Rainfalls of 10 inches, or more, during 24 hours, in the United States* (Woolard, 1942) and the Corps of Engineers' *Storm rainfall in the United States, Depth-area-duration data* (Volumes 1 and 2) (Department of the Army, 1973) were reviewed. Events missing in our datasets were added manually to corresponding stations using information from the publications and from NCDC's COOP climatological observations forms. When possible, the additional NCDC data were downloaded from the High Plains Regional Climate Center's database. Consideration was also given to cases where the 24-hour unconstrained value from the observation form or publication was much greater than the corresponding 1-day constrained value from our datasets; adjustments in the recorded values were made where warranted.

1.1.2. Station screening

77 cases where three stations were merged together to increase record lengths were reviewed to ensure that the correct data were kept during any overlapping periods and that the appropriate station ID was assigned to the resulting data.

1.1.3. Quality control of AMS

The 1-hour data from the Remote Automated Weather Stations (RAWS) database were subjected to additional quality control because numerous questionable values were observed in the formatted data. At stations with at least 20 years of data, all hourly precipitation values that were outside the realm of possibility were set to missing. Further quality control was done by hand-checking values that were feasible, but questionable.

Final screening of high and low outliers in annual maximum series (AMS) was done for all durations between 15-minutes and 60-days. The outliers are being verified, corrected, or removed from the dataset.

1.1.4. Mean annual maxima analysis

Spatial analysis of at-station mean annual maxima estimates (MAMs) for 1-hour, 1-day and 10-day durations is in progress. During the analysis, station MAM data are reviewed relative to MAMs at nearby stations. The goal is to identify locations where MAMs are affected by short periods of record or missed heavy events. Preliminary mean annual maxima for 15-minute, 1-hour, 1-day and 10-day were sent to the PRISM Group at Oregon State University for spatial interpolation.

1.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2012)

In the next reporting period, the following tasks will be completed: analysis of spatial patterns in mean annual maxima, trend analysis of 1-hour and 1-day AMS, and regionalization and preliminary at-station frequency analysis.

1.3. PROJECT SCHEDULE

Completion dates for remaining tasks are revised to reflect the impact of loss of personnel and issues with computing resources. As a result, the publication date is revised to January 2013.

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) [Near completion]

Regionalization and frequency analysis [November 2010; revised to March 2012]

Initial spatial interpolation of precipitation frequency (PF) estimates and consistency checks across durations [August 2011, revised to May 2012]

Peer review [September 2011, revised to July 2012]

Revision of PF estimates [December 2011, revised to November 2012]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [April 2012, revised to January 2013]

Web publication [May 2012, revised to January 2013]

2. PRECIPITATION FREQUENCY PROJECT FOR THE MIDWESTERN STATES

2.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2011)

The 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 (Figure 3). To facilitate a more efficient process, Southeastern (see Section 1) and Midwestern precipitation frequency projects are being done simultaneously. Because of that, some of the results shown in this report apply for both projects.

Significant loss of HDSC personnel in recent months and a failure of the Office of Hydrologic Development's (OHD) computing storage cluster in December have impacted the progress of this project during this report period (see Section III for details).

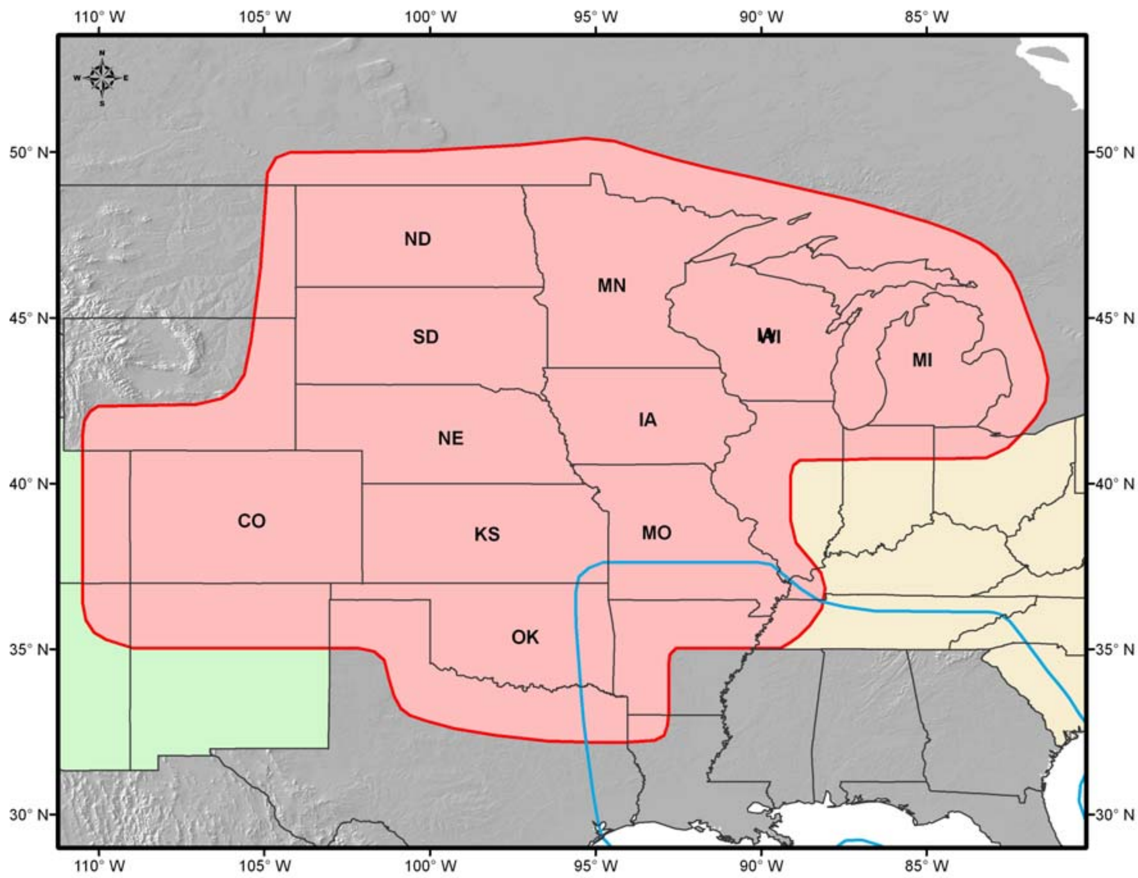

Figure 3. Midwestern precipitation frequency project area (shown in red). Also shown is the border of the Southeastern precipitation frequency project area (blue line).

2.1.1. Data collection and formatting

Existing 15-minute, hourly and daily stations were extended with newly released data from the National Climatic Data Center (NCDC). Data at 15-minute and hourly NCDC stations were extended through December 2010 and data at daily stations through October 2011.

Effort was made to confirm that all significant events recorded in various publications were included in our datasets. Among others, significant events from Monthly Weather Review's *Rainfalls of 10 inches, or more, during 24 hours, in the United States* (Woolard, 1942) and the Corps of Engineers' *Storm rainfall in the United States, Depth-area-duration data* (Volumes 1 and 2) (Department of the Army, 1973) were reviewed. Events missing in our datasets were added manually to corresponding stations using information from the publications and from NCDC's COOP climatological observations forms. When possible, the additional NCDC data were downloaded from the High Plains Regional Climate Center's database. Consideration was also given to cases where the 24-hour unconstrained value from the observation form or publication was much greater than the corresponding 1-day constrained value from our datasets; adjustments in the recorded values were made where warranted.

2.1.2. Station screening

77 cases where three stations were merged together to increase record lengths were reviewed to ensure that the correct data were kept during any overlapping periods and that the appropriate station ID was assigned to the resulting data.

2.1.3. Extraction of AMS

Software to extract supplemental annual maximum series and calculate rainfall frequency estimates for 90-, 180- and 365–day durations, requested by several Missouri state agencies, was written.

2.1.4. Quality control of AMS

The 1-hour data from the Remote Automated Weather Stations (RAWS) database were subjected to additional quality control because numerous questionable values were observed in the formatted data. At stations with at least 20 years of data, all hourly precipitation values that were outside the realm of possibility were set to missing. Further quality control was done by hand-checking values that were feasible, but questionable.

Final screening of high and low outliers in annual maximum series (AMS) was done for all durations between 15-minutes and 60-days. The outliers are being verified, corrected, or removed from the dataset.

2.1.5. Mean annual maxima analysis

Spatial analysis of at-station mean annual maxima estimates (MAMs) for 1-hour, 1-day and 10-day durations is in progress. During the analysis, station MAM data are reviewed relative to MAMs at nearby stations. The goal is to identify locations where MAMs are affected by short periods of record or missed heavy events. Preliminary mean annual maxima for 15-minute, 1-hour, 1-day and 10-day were sent to the PRISM Group at Oregon State University for spatial interpolation.

2.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2012)

In the next reporting period, the following tasks will be completed: investigation of outliers in the AMS for all remaining durations, trend analysis for 1-hour and 1-day durations, regionalization and preliminary frequency analysis. Spatial patterns in mean annual maxima will be investigated.

2.3. PROJECT SCHEDULE

Completion dates for remaining tasks are revised to reflect the impact of loss of personnel and issues with computing resources. As a result, the publication date is revised to January 2013.

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) [Near completion]

Regionalization and frequency analysis [November 2010; revised to March 2012]

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Peer review [September 2011, revised to July 2012]

Revision of PF estimates [December 2011, revised to November 2012]

Remaining tasks (e.g., development of precipitation frequency estimates for partial duration series, seasonality, temporal distributions, documentation) [April 2012, revised to January 2013]

Web publication [May 2012, revised to January 2013]

3. PRECIPITATION FREQUENCY PROJECT FOR ALASKA

3.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2011)

The University of Alaska, Fairbanks (UAF) and HDSC are jointly working on this project. A presentation on the project tasks, status and main deliverables was given to the members of the Interagency Hydrology Committee of Alaska on October 26.

Significant loss of HDSC personnel in recent months and a failure of the Office of Hydrologic Development's (OHD) computing storage cluster in December have impacted the progress of this project during this report period (see Section III for details). Therefore, the publication date is pushed from the end of December to the end of January 2012.

3.1.1. Rainfall AMS extraction

HDSC performed separate rainfall (i.e., liquid only) and precipitation frequency analyses for 1-hour, 3-hour, 6-hour, 12-hour and 24-hour using the Generalized Extreme Value (GEV) distribution with parameters estimated from L-moment statistics. Ratios of rainfall and precipitation frequency estimates were examined for selected annual exceedance probabilities (AEPs). The relationships were station specific and no spatial patterns were observed. Ratios were typically higher than 0.96 for all stations across all AEPs, suggesting very little difference in frequency estimates between total and liquid precipitation across all durations.

It should be noted that no high elevation stations were available for this analysis. A summary of the investigation will be included in the NOAA Atlas 14 Volume 7 documentation.

3.1.2. Spatial interpolation of mean annual maxima

At-station MAM estimates for the range of durations 60-minutes through 60-days were sent to Oregon State University's PRISM Group for spatial interpolation using their hybrid statistical-geographic approach for mapping climate data named Parameter-elevation Regressions on Independent Slopes Model (PRISM). HDSC evaluated spatial patterns in mean annual maxima (MAMs) grids for selected durations. Some 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. We made several iterations with the PRISM Group to ensure satisfactory MAM patterns.

During these iterations, the PRISM Group determined that the spatial interpolation technique used for previous volumes was not adequate for the Alaska hourly data due to a lack of station data and strong spatial gradients in the 24-hour values, particularly in southern Alaska. Therefore, the original PRISM approach that relates mean annual maxima to mean annual precipitation was adjusted. The final documentation for the Volume will include a report from the PRISM Group detailing their procedures.

3.1.3. Regionalization for frequency analysis

HDSC finalized regionalization work this quarter. Regions for each station were initially created by grouping the closest 10 stations. Stations were then added to or removed from the 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 regions.

Typically, final regions included between 5 to 9 stations with a cumulative number of data years between 150 and 250 for daily durations and 40 and 80 for hourly durations. However, since there were large portions of the project area with very few stations, final numbers of stations per region are as low as a single station and/or have less than 20 data years, especially for hourly durations.

Finally, regional L-moments for 1-hour to 60-day durations were estimated for all stations used in frequency analysis.

3.1.4. Precipitation frequency estimation with confidence limits at stations

During this quarter, precipitation frequency estimates and their 90% confidence intervals were computed and reviewed for all durations.

a. Precipitation frequency estimates

Daily and hourly durations. For each station and for each duration 1-hour and longer, regional L-moment statistics were used to calculate the parameters of the GEV distribution and to produce precipitation frequency estimates. Since regional L-moments, and consequently, precipitation frequency estimates, were calculated independently for each duration, they were smoothed across durations using cubic spline functions to improve resulting depth-duration-frequency (DDF) curves.

Sub-hourly durations. 5-minute, 10-minute, 15-minute and 30-minute estimates were calculated using scaling factors from 60-minute estimates. The scaling factors were developed through analysis of average ratios of n-minute annual maxima from the available 36 NCDC n-minute stations to corresponding unconstrained 60-minute annual maxima. Given the relatively small amount of data available and after reviewing the ratios spatially, it was decided that the final scaling factors would be calculated by taking averages of all quality controlled ratios in the project area. The scaling factors for the 5-minute, 10-minute, 15-minute, and 30-minute durations were calculated as 0.35, 0.47, 0.55 and 0.73, respectively.

b. Confidence limits

A Monte Carlo simulation procedure, as described in Hosking and Wallis (1997), was used to construct 90% confidence intervals (i.e., 5% and 95% confidence limits) on the precipitation frequency curves. Since AMS data from different stations could be correlated (especially for longer durations), the algorithm was adjusted to account for inter-station correlation.

3.1.5. Spatial interpolation of precipitation frequency estimates

HDSC revised the spatial interpolation technique for the precipitation frequency estimates, as was used in NOAA Atlas 14 Volume 6, to better address the scarcity of data in a significant portion of Alaska, especially at sub-daily durations. The alternative technique takes advantage of regional characteristics of ratios of precipitation frequency estimates at consecutive frequencies. The consistency in grid cell values across all durations and frequencies was also checked to ensure there are no any duration-based internal consistency violations (e.g., 24-hour estimate < 12-hour estimate).

3.1.6. Supplemental information

HDSC completed an analysis of temporal distributions of heavy precipitation, seasonality of AMS, and trends in the AMS data on the finalized dataset. Temporal distributions of events greater than the 50% annual exceedance probability were computed for the 6-, 12-, 24-, and 96-hour durations. Data were grouped into two climate regions to increase sample size for both the temporal distributions and the seasonality information. The two climate regions are combinations of regions defined during the AMS extraction process and were delineated based on extreme precipitation characteristics expressed through 24-hour mean annual maximum (MAM) estimates, mean annual precipitation (MAP), elevation, latitude, and proximity to the coast.

An analysis for trends in AMS magnitudes was conducted for 1-hour and 1-day durations. Because statistical tests at both durations indicated no statistically-significant trends in the AMS magnitudes, the assumption of stationary climate was accepted for this project area and no adjustment to AMS data was recommended.

3.1.7. Documentation

The text of the final documentation, which will be similar to previous volumes but with an additional appendix to discuss the results of the bias correction for undercatch investigation done by the UAF, is drafted and is currently under review.

3.1.8. Web page

HDSC prepared Precipitation Frequency Data Server (PFDS) web pages for Alaska to deliver the project results. Supplementary information for the web page, such as, cartographic maps and metadata for GIS datasets, is near completion.

3.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2012)

The project will be completed in the next reporting period.

3.3. PROJECT SCHEDULE

The publication date for this project was pushed to January 2012 due to the impact of loss of personnel and issues with computing resources.

UAF and HDSC: data collection, formatting, and initial quality control [Complete]

UAF and HDSC: extraction of annual maximum series (AMS) for precipitation and rainfall; additional quality control and data reliability tests (e.g., outliers, trend analysis, independence, consistency across durations, duplicate stations, candidates for merging) [Complete]

HDSC: regionalization and frequency analysis [Complete]

HDSC: initial spatial interpolation of PF estimates and consistency checks across durations [Complete]

HDSC and UAF: peer review [Complete]

HDSC: revision of PF estimates [Complete]

HDSC: remaining tasks (e.g., development of precipitation frequency estimates for PD series, seasonality, temporal distributions) [Complete]

HDSC: web publication of estimates [November 2011, revised to January 2012]

HDSC and UAF: documentation [December 2011, revised to January 2012]

4. AREAL REDUCTION FACTORS

4.1. PROGRESS IN THIS REPORTING PERIOD (Oct - Dec 2011)

Areal reduction factors (ARFs) are needed to convert average point precipitation frequency estimates to areal estimates with the same recurrence interval for any area of interest. HDSC is testing two existing methods and developing a new copula-based method for calculating ARF. Please see the July – September 2010 Quarterly Report (http://www.nws.noaa.gov/ohd/hdsc/current-projects/pdfs/HDSC_PR_Oct10.pdf) for more information on the methods.

Upon the completion of the quality control of the 1-hour data in the Midwest project (Section 2), data for the state of Oklahoma was gathered and the testing of proposed methods began. Software codes and gauge data files were revisited to prepare input files for the analysis. Work also began to process radar data for use in the investigation.

The new copula-based methodology accounts for spatial dependence structure of precipitation fields and incorporates precipitation intermittency directly in the parent distribution. Testing this method, ARFs were computed as ratios of point and areal estimates obtained from corresponding joint distributions. Preliminary results were obtained for average recurrence intervals of 20-years through 1,000-years. The results suggest that the copula-based approach improves the estimation of ARFs by effectively incorporating the spatial dependence structure and the intermittency in precipitation fields. Preliminary results for the copula-based approach were presented and well received at the 2011 Fall American Geophysical Union (AGU) Meeting in San Francisco, California.

However, this project was again put on hold to minimize the impact of loss of personnel and issues with computing resources on precipitation frequency projects.

4.2. PROJECTED ACTIVITIES FOR THE NEXT REPORTING PERIOD (Jan - Mar 2012)

In the next quarter, limited activity on this project is planned.

4.3. PROJECT SCHEDULE

This project began on April 1, 2010. It is expected to be completed by April 2013.

III. OTHER

1. RECENT PRESENTATIONS

Ishani Roy of HDSC presented *A Copula Based Approach for Estimation of Areal Reduction Factors* at the American Geophysical Union 2011 Fall Meeting in San Francisco in December 2011.

HDSC and UAF gave a Go-To-Meeting presentation on 26th of October for the members of the Interagency Hydrology Committee of Alaska on the precipitation frequency project for Alaska.

In December, "Trends in Rainfall Exceedances in the Observed Record in Selected Areas of the United States", authored by Geoffrey M. Bonnin, Kazungu Maitaria, and Michael Yekta, was published in the Journal of the American Water Resources Association (JAWRA). This article is part of a selection from the articles presented at the Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management, January 13-15, 2010 at Boulder, Colorado, and subsequently published by JAWRA.

2. PERSONNEL

Two members of HDSC left or retired in December 2011. We are taking steps to fill the vacant positions. Sarah Heim, a contractor, continued to contribute to the web development activities for the Alaska project during this report period. Michael Yetka, a Government employee and long-time member of HDSC, retired. He will continue to support database management tasks on a sporadic part-time basis as we transition to new staff.

3. COMPUTING ENVIRONMENT

During the reporting period we experienced computing system instabilities. In addition, there was a major failure of the disk cluster systems which required the rebuilding of the entire cluster from backups. These outages resulted in reduced productivity during October and November and an almost complete loss of productivity in December. In addition to restoring the systems and successfully restoring information from backups, steps have been and continue to be taken to re-engineer the computing environment to provide a greater level of reliability.