138 ANALYSIS OF FREEZING RAIN PATTERNS IN THE SOUTH CENTRAL UNITED STATES: 1979–2009

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1. INTRODUCTION

Freezing rain (FZRA) events are among the most hazardous and destructive winter weather phenomena in the United States. Ice storms (heavy FZRA events) can severely damage property, overhead power and communication lines, transportation routes, and the natural environment. These storms can cause millions or even billions of dollars in damages and economic losses (Changnon 2003; Ross and Lott 2003; NOAA 2003; NOAA 2010).

As synoptic weather patterns shift over time in response to climate change and variations, it is possible that regional and seasonal FZRA patterns may be altered. Because individual FZRA events generally occur within a narrow band, regional patterns—and their evolution over time—are of great interest to sectors such as insurance, transportation, and civil infrastructure as well as to society as a whole. Understanding FZRA spatial patterns and temporal trends at the regional scale can help to prepare for and adapt to potential future events.

Several studies have developed climatologies of freezing rain occurrences in the U.S. on regional (e.g., Cortinas 2000) or national (e.g., Cortinas et al. 2004; Houston and Changnon, 2007) scales and others have examined spatial and temporal trends (e.g., Changnon and Karl 2003; Changnon and Bigley 2005). These climatologies have been based on available observational data. Historically, there have not been an adequate number of weather stations to accurately determine regional-scale FZRA patterns across the entire U.S., particularly in rural land areas. Additionally, many stations only report data once per day, and often precipitation accumulation is not available. Therefore, reanalysis data was chosen as the best candidate for spatial and temporal continuity. Reanalysis data provide continuous forecasted weather conditions in areas that either do not have observational data or have only sparse data.

The purpose of this initial work is to develop a comprehensive reanalysis seasonal climatology to assess trends, including the frequency, intensity, and duration of FZRA events as well as temporal and spatial distributions in localized regions of the South Central United States. This study appears to be the first effort to estimate regional-scale freezing rain climatologies in the U.S. using reanalysis data.

2. DATA AND METHODOLOGY

The National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) 32-kilometer (1/8°) gridded three-hourly forecast data (Mesinger et al. 2006) were obtained for the period 1979–2009 to develop a climatology and to examine FZRA trends for eastern Oklahoma and western and central Arkansas. This region was chosen because it is subject to episodic freezing rain events. The NARR dataset was selected because of its high resolution and frequent forecast periods. The time period was selected because of the data availability, i.e., at the time of this analysis, the period of record for NARR data spanned from January 1, 1979 to December 31, 2009. The data were analyzed seasonally, monthly, and by event. A season was defined as beginning in September and ending the following April. The NARR 'flags' an FZRA forecast with a '1'. If the accumulation is some other type of precipitation, then the FZRA flag is '0'. In order to define a "freezing rain event" for climatological purposes, forecasts of FRZA that occurred within 12 hours of a previous FZRA forecast were summed together

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and defined as an event. FZRA that occurred more than 12 hours after the previous FZRA forecast was treated as a new event. This work did not examine any types of precipitation other than FZRA.

Gridded reanalysis data were compared with geographically corresponding relevant station observations for validation of the model data. Figure 1 shows six stations that were selected for comparison: Tulsa, OK; McAlester, OK; Fayetteville, AR (Drake Field); Fort Smith, AR; Little Rock, AR (Adams Field); and Texarkana, AR. In order to compare observed accumulations with reanalysis estimates for specific FZRA events, data were obtained from the NOAA National Climatic Data Center (NCDC) hourly global surface dataset. A spatial analysis was conducted to compare observed station precipitation totals and surface temperatures with corresponding NARR gridded data for an FZRA event on 27 December 1990. This event was selected because the NARR FZRA total accumulations on this date varied widely for the six different grids that were examined. Observations were then obtained for each corresponding station via NCDC's surface hourly observations. Because comparisons were made between a 32-kilometer grid and a single station point, it was not expected that the values would perfectly match; however, the general spatial pattern of accumulation was expected to be similar.

A separate climatology analysis was also conducted to compare the number of reanalysis FZRA days with three first order station (Tulsa, Little Rock, Fort Smith) and one cooperative station (Fayetteville) climatologies, as developed by NOAA (2003). NOAA (2003) was also used to compare total number of reanalysis FZRA hours with the three first order stations listed above. Cooperative stations typically report data once every 24 hours and thus no hourly FZRA data was available for Fayetteville. Reanalysis seasonal data begin for 1979/1980 season and NOAA (2003) climatology is for observational data available through the 1999/2000 season. Data for Fayetteville was only available through 1990/1991. Climatologies were not available for Texarkana or McAlester (FZRA days and hours). The NOAA (2003) dataset does not include precipitation amounts.

3. RESULTS

Table 1 provides reanalysis and observational data for an FZRA event that occurred on 27 December 1990. Comparing all data, reanalysis minimum and maximum surface temperatures during the event were generally within 1.5°C of the minimum and maximum observations. It is noted that the reanalysis data tended to be consistently cooler than the observed values. Overall, the maximum reanalysis temperature during the event was 0.9°C at McAlester and the maximum observed temperature was 1.7°C, also at McAlester as well as Little Rock. The surface temperature for FZRA events is important as slight shifts in the temperature can alter the precipitation type, i.e., warmer temperatures would likely bring a rain event. All stations recorded at least one hour of observed freezing precipitation on this date. Among the stations, Tulsa recorded one hour of freezing drizzle but primarily noted snow showers; the corresponding reanalysis forecast for Tulsa region did not flag FZRA at all. For four stations the observation and reanalysis accumulations compared well: Little Rock (18 mm and 20.4 mm, respectively); Fort Smith (5.2 mm and 3.5 mm); McAlester (3.5 mm and 2.9 mm); Fayetteville (1 mm and 3.4 mm). Texarkana forecasted accumulation was the largest among all stations at 24.9 mm. Upon examination, the precipitation was not included in the observational record and thus no comparison could be made. It is important to note that reanalysis forecasts only flag one precipitation type per three-hour forecast (rain or snow or sleet or freezing rain) whereas observations can report all precipitation types that occurred during an observation period (e.g., sleet mixed with freezing rain and snow). Unfortunately, when multiple precipitation types are reported, it is not possible to determine how much accumulation can be attributed to a single type. It should also be noted that observational data is not necessarily the 'truth', especially in the era of automated precipitation typing.

Reanalysis FZRA days and total number of FZRA hours were compared with available observations. Initial comparisons are promising. As shown in Figure 2, reanalysis generally captured the monthly trend and number of FZRA days at each station with a few exceptions, most notably Tulsa (November, January) and Fayetteville (January). The number of reanalysis FZRA days for each month is consistently lower than the reported observations for Tulsa. However, reanalysis forecasts are scattered higher/lower than reported observations at the other stations. Thus, there does not appear to be a bias toward under or overestimation by the reanalysis. Total number of observed versus reanalysis FZRA days for all months combined for Little Rock, Fort Smith, and Fayetteville compare well (see Figure 3); however, nearly 70 percent more FZRA days were observed for Tulsa compared with the reanalysis. It is noted that the observations are on the order of one hour while the NARR data are provided in three hourly forecasts. However, reasonable comparisons can still be made. Figure 4 shows the number of reported FZRA hours compared with the reanalysis minimum number of hours (i.e., one hour of FZRA in the three-hour reanalysis forecast) and maximum number of hours (i.e., three hours of FZRA in the three-hour reanalysis forecast). The observed number of hours falls between the possible minimum and maximum forecast hours at Little Rock and Fort Smith. However, the number of FZRA observations for Tulsa is about 25 percent higher than the maximum number of reanalysis hours.

4. OTHER ANALYSIS AND FUTURE WORK

Additional FZRA climatology information was developed for each of the grid points presented in this work. This includes the earliest and latest FZRA event date per season, maximum FZRA event precipitation per season, total FZRA accumulation for each season, and number of FZRA events per month (within a single season) and per season. To assess temporal trends in number of events and individual event accumulation totals, events were separated into six five-year periods (e.g. 1979/1980–1983/1984) and the events were summed by total accumulation (0–2.53 mm (0–0.1 inch); 2.54–6.34 mm (0.11–0.25 inch); 6.35–12.69 mm (0.26–0.50 inch); greater than 12.69 mm (0.51 inch). Combining seasons into multi-year periods helps to eliminate year-to-year variability and provide a more accurate portrayal of possible trends in the frequency and magnitude of events for a particular area. The climatology will be updated on an annual basis as the newest seasonal NARR data becomes available. It is expected that temporal and spatial trends will become more discernable as the dataset is extended over time.

The initial work was confined to analysis of six 32-kilometer grid cells located within eastern Oklahoma and western and central Arkansas. As discussed in Section 2, the grids correspond geographically to stations with observational data and, in general, the reanalysis data appears to compare well with observational data. The next step will be to expand the analysis geographically to include all regions within the U.S. that are subject to FZRA events. Temporal and random spatial comparisons between the NARR forecasts and observations will be conducted as the dataset is expanded. The NARR data will be developed into a comprehensive FZRA dataset as well as an interactive climatology product that will be made publicly available through NOAA's National Climatic Data Center. As envisioned, a user will be able to select their point of interest and be provided with a complete NARR FZRA climatology of that particular location.

5. REFERENCES

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Table 1. Comparison of three-hourly NARR freezing rain and surface temperature forecast with NCDC station surface hourly observations for 27 December 1990.

Reanalysis Forecast						Station Observations			
Location	Forecast duration (UTC)	Precip (mm)	Min Temp (°C)	Max Temp (°C)		Precip (mm)	Min Temp (°C)	Max Temp (°C)	Hours of FZRA
Tulsa	0000-2359	0				2	-0.6	0	1
Little Rock	0000-2059	20.4	-2.0	0.1		18[1]	-0.6	1.7[1]	7
Fort Smith	0600-1759	3.5	-2.0	0.3		5.2	-0.6	0.6	13
McAlester	0000-1759	2.9	-1.4	0.9		3.5	-0.5	1.7	10
Fayetteville	0600-1759	3.4	-3.0	-0.5		1	-1.0	1.1	6
Texarkana	0600-1759	24.9	-1.5	0.1		NA[2]	0	1.1	3

[1]Precipitation was recorded every six hours. A reported five mm fell during the period 1800-2359, which includes three more hours than the reanalysis forecast. During this time, 'light or moderate solid precipitation' was reported.
[2]Observed precipitation amounts were not reported during this time.

Figure 1. South Central U.S. locations chosen to compare NARR three-hourly freezing rain forecasts with surface observations.

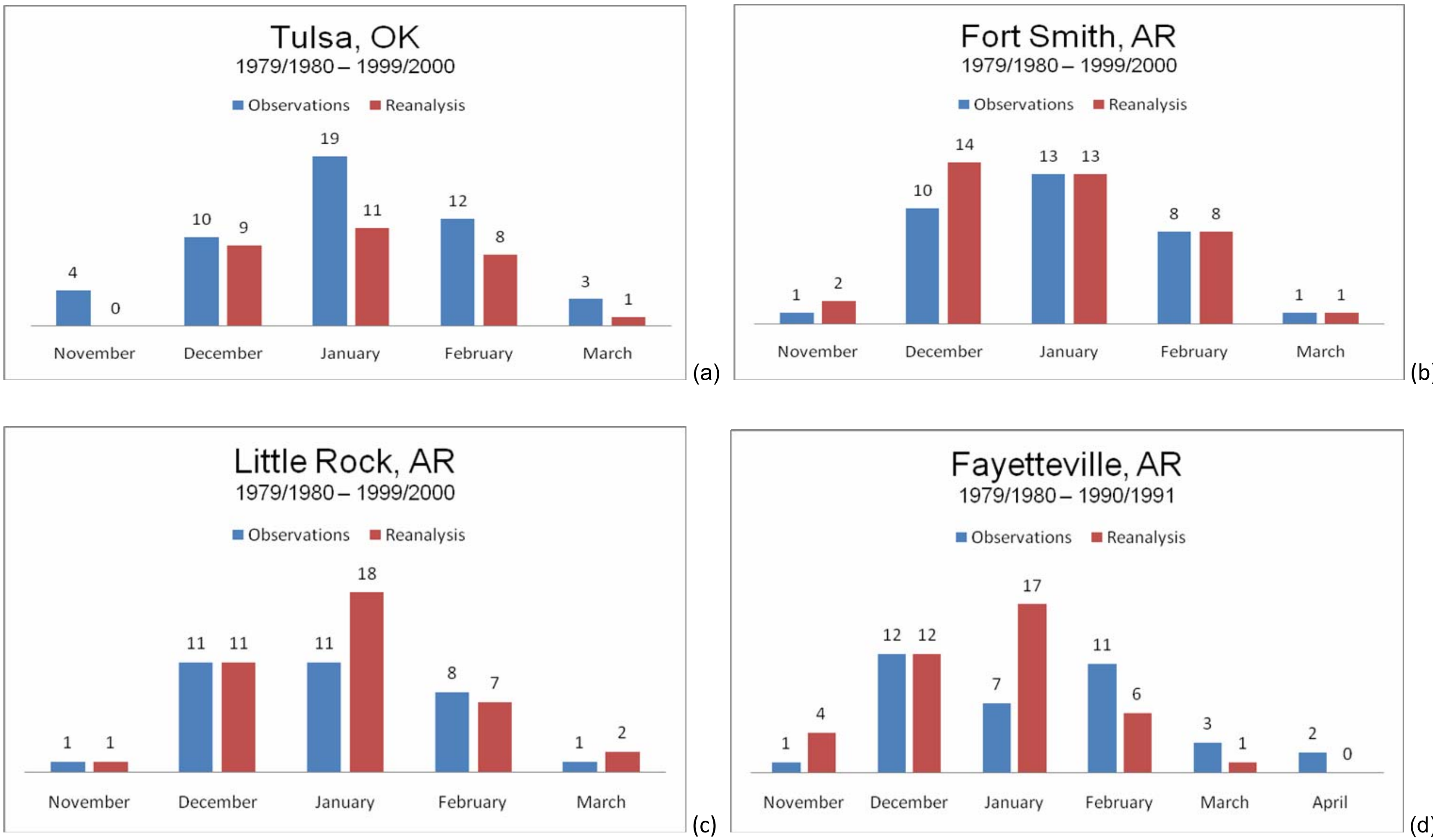

Figure 2. Comparison of total number of freezing rain days per month for entire period of comparison between first order airport station observations and NARR three-hourly forecast data for (a) Tulsa, OK (b) Fort Smith, AR, and (c) Little Rock, AR, and between cooperative station observations and NARR three-hourly forecast data for (d) Fayetteville, AR..

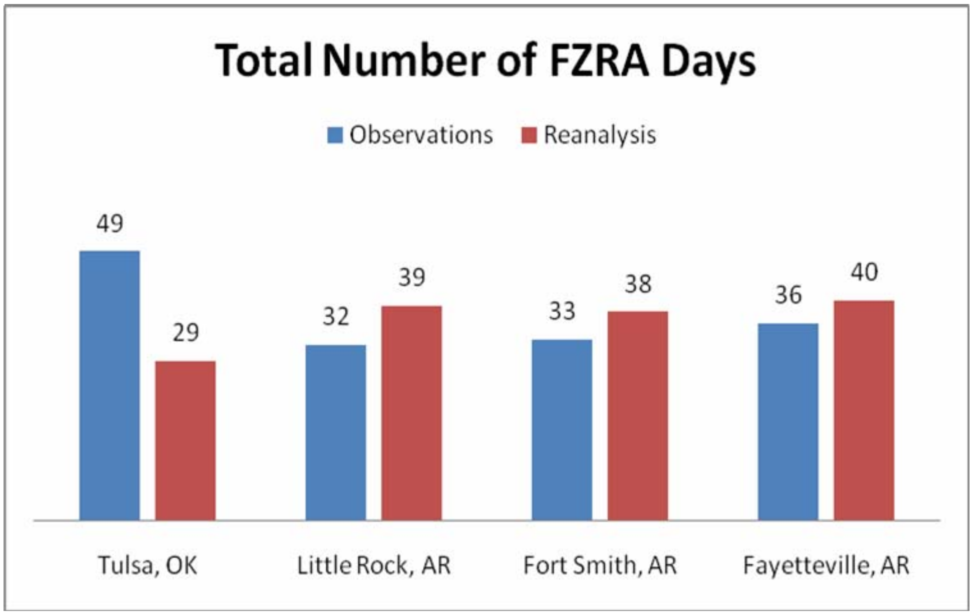

Figure 3. Comparison between observations and NARR three-hourly forecast data for total number of freezing rain days for the period 1979/1980-1999/2000 for Tulsa, OK, Little Rock, AR, and Fort Smith, AR and for the period 1979/1980-1990/1991 for Fayetteville, AR.

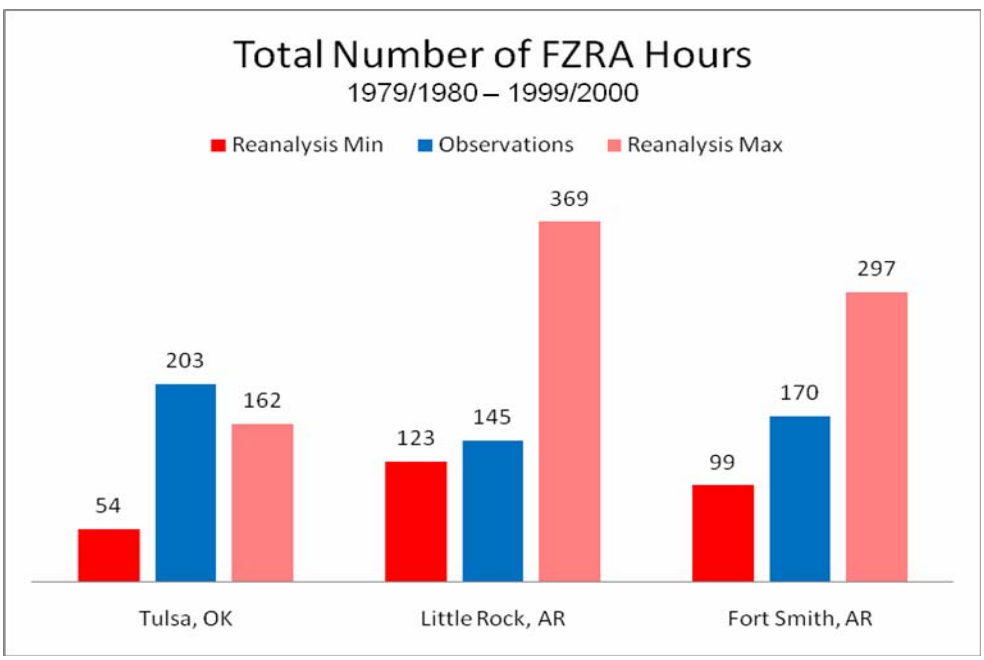

Figure 4. Comparison of total number of observed freezing rain hours at three first order stations with freezing rain hours derived from NARR three-hourly forecasts. Reanalysis Min indicates the minimum number of NARR forecast freezing rain hours (i.e., one hour in the three-hour forecast) and Reanalysis Max indicates the maximum number of forecast freezing rain hours (i.e., three hours in the three-hour forecast).