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CoCoRaHs in Missouri: Four Years Later, the Importance of Observations

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Abstract *On 1 March 2006, Missouri became the 11th state to join the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS). CoCoRaHS is a national volunteer network of individuals who have agreed to measure and report precipitation observations daily. This program was established in 1998 by the Colorado State Climate Office. On 12 March, 2006 CoCoRaHs quickly demonstrated its usefulness during the severe weather events of that day when there were several reports of large hail. Since then, Missouri CoCoRaHS network receives about 250 reports per day. This data can be used to study severe weather events such as the passage of Tropical Depression Gustav and Tropical Storm Ike through Missouri over a 10 day period bookended by 4 and 14 September 2008. Here we will compare the CoCoRaHS volunteer rainfall totals to RADAR derived estimates taken from the National Weather Service (NWS) as well as the Cooperative Site measurements. CoCoRaHS data was even incorporated by the local NWS to summarize these events. CoCoRaHS data is currently used by all six NWS offices and the four River Forecast Centers that serve the state of Missouri as well as by other state and federal agencies and several television stations. The data have been used to dispatch flash flood information to the NWS and to make flood and drought assessments for the Missouri departments of Agriculture and Natural Resources. Public works departments, insurance companies, contractors and farmers have also used the data for documentation and management decisions. The Missouri CoCoRaHS network has proven to be a very valuable tool for precipitation measurement, and here we demonstrate this by comparing the CoCoRaHS data to different types of precipitation graphics provided by the NWS.*

1. Introduction

Most people are familiar with the sound of rain, but to a certain group of people this is the sound of opportunity to help scientists embark on the study of precipitation and its distribution within weather events (e.g., Market and Cissell, 2002). These studies can help scientists gain an understanding of the dynamic mechanisms leading to the formation, maintenance, and decay of these events. The volunteer observers who help scientists, hydrologists, meteorologists, climatologists and other personnel through precipitation reports, observations, and analysis are the members of the Community Collaborative Rain, Hail and Snow (CoCoRaHS) Network.

CoCoRaHS is a unique, diverse and non-profit organization comprised of mostly amateur volunteers who measure precipitation once-per-day nationwide. The coordinators of the organization begin with those on the national level, and then down to the state and regional levels. The most important attribute of CoCoRaHS however, is the vast network of its volunteers. Volunteers in the organization are meteorological professionals at universities, the NWS, television stations, and the general public, and these are comprised of people from different ethnic backgrounds. Volunteer weather observation has a long history in the United States, especially within programs under the direction of the NWS. Examples are the National Oceanic and Atmospheric Administration (NOAA) Cooperative Observers program (COOP — COOP, 2009) established in 1890, or SKYWARN which was established about 35 years ago (SKYWARN, 2009).

Members of CoCoRaHS, although diverse in many ways, all have one thing in common: they all love the weather. Weather is a fascinating subject that directly impacts how we live, when and where to conduct outside activities, and the kind of products we buy each day. One mission of the meteorological community is the observation, reports and analysis of precipitation. Thus, the purpose of CoCoRaHS is the observation, report, and analysis of precipitation in order to provide scientists with the highest quality data for educational purposes and research applications.

Why is the CoCoRaHS organization so focused on the precipitation characteristic of weather? Precipitation is a vital and essential part of our lives. Precipitation affects all of us in a variety of ways, falls in many forms and varies greatly in amount and intensity throughout the world. There are many factors to look at when analyzing precipitation: precipitation amounts are affected greatly by topography, strength of a storm system, amount of moisture in each system, and season, among others.

The creation of the CoCoRaHS network was a direct result of a devastating localized flash flooding event that occurred on 28 July, 1997 over Fort Collins, CO (CoCoRaHS, 1998). A series of thunderstorms produced over a foot of rain in several hours in certain parts of the city; other parts of the same city only got moderate rainfall. Event rainfall totals from 28–29 July, 1997 ranged from 14.5 inches over Western parts of Fort Collins (in the Foothills), while Eastern sections of the city (in the plains) reported less than two inches. For a period of 90 minutes, extreme downpours totaled more than five inches during the worst part of the event.

The devastating flash flood killed five people and produced over $200 million dollars in damage. One year later, a group organized under Dr. Nolan Doesken of the Colorado Climate Center at Colorado State University created a network to observe precipitation, rainfall rates, and other attributes for localized events. The network for precipitation reports, observations and analysis has now expanded into a national organization in all 50 United States.

In this paper, an overview of CoCoRaHS in Missouri will be provided in section two. In section three, a comparison of the CoCoRaHS observations to radar derived estimates of precipitation will be compared for two remnant hurricanes which crossed Missouri in 2008. Finally, a summary of this work will be given, and the conclusions will be reviewed.

2. COCORAHS in Missouri begins March 2006

CoCoRaHS has been a national organization since 1998, but Missouri's affiliation began officially on 1 March 2006. Missouri was the 11th state to join the network. The usefulness of CoCoRaHS observations in Missouri were demonstrated on 12 March 2006 when a severe weather outbreak impacted a large part of the midwest. (see Fig. 1). Several individuals forwarded their reports during the severe weather, thus CoCoRaHS in Missouri was born. Note that on that day there were three reports of two-inch hail stones, including a report of three-inch hail stones near Columbia, MO. CoCoRaHS hail reports, as well as intense rainfall reports, are forwarded to their respective NWS Office.

There are currently 877 CoCoRaHS observers listed in the Missouri data-base, and of these, 372 have reported within the last month. Missourians routinely submit about 250 reports daily. During the month of June, 2009, for example, submissions ranged from a low of 247 (22 June 2009) to a high of 317 (3 June 2009) reports on any given day. The average daily state reporting total was 282. The number of observations is larger following days when rainfall occurs statewide. There were also 19 hail reports during June, 2009, but no more than four on any particular day. During the cold season, snowfall reports have been useful in identifying locally heavy snowfall snow accumulations, especially away from urban centers. It is difficult to assess the demographics of age since few participants added this voluntary information upon signup. There were volunteers of all age groups found in Missouri. Professional meteorologists (academic, government, and private sector) accounted for only 14 of the total observers.

CoCoRaHS now has observers in 113 of the 114 counties in Missouri. The spatial distribution across the state shows that the number of observers is strongly weighted toward the southwest part of Missouri which includes much of the KY- 3 TV (Springfield, MO NBC affiliate) viewing area, and the county warning area of the Springfield National Weather Service (SGF). KY – 3 TV has been very active in recruiting CoCoRaHS observers and using this data. Eight of the ten counties with the most observers were in southwest Missouri. The number of observers is also strongly correlated to urban areas and/or university centers. Table 1 shows the number of observers in the four largest urban centers and the surrounding counties. Table 2 shows the top ten counties by number of observers.

CoCoRaHS observers are asked to submit their rain gauge readings online at http://www.cocorahs.org each morning for the 24-hr period ending at 7 a.m. local time. Each observer is asked to purchase, or is given, a standard four-inch diameter, raised-edge rain gauge. These gauges are made of heavy duty plastic and are recommended by the national CoCoRaHS coordinators. The data produced by the network is used in a variety of ways and applications. The data are currently used by all six National Weather Service Forecast Offices (NWSFO) and four River Forecast Centers serving Missouri. There are also other state and federal agencies that incorporate the CoCoRaHS reports, observations and data into their services. The data have been especially helpful with dispatching flash flood information to the NWS. The Missouri Departments of Agriculture and

Figure 1. The CoCoRaHS map of Missouri for 12 March 2006 showing hail size.

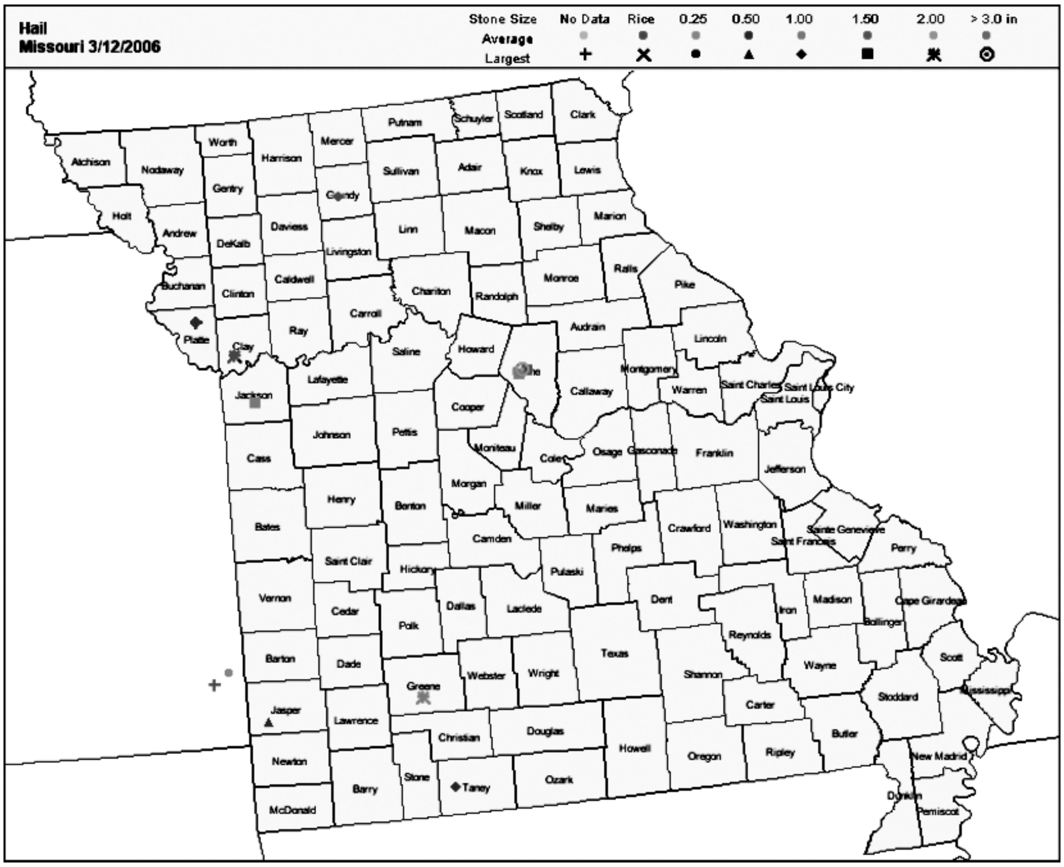


Table 1. The number of observers in the counties surrounding the four largest urban areas in Missouri.

Urban Areas	Observer Numbers
Springfield	183
Columbia	81
Saint Louis	67
Kansas City	66

Table 2. The top eleven number of observers in Missouri counties.

County	Observer Numbers
Greene	71
Boone	42
Christian	42
Texas	30
Stone	25
Taney	23
Lawrence	21
Barry	20
Howell	20
St. Louis	20
Webster	20

Natural Resources use this information for flood and drought assessments. CoCoRaHS data has even been used for documentation and management decisions for different work departments, insurance companies, contractors, farmers and agricultural interest occupations, and even in a court of law.

3. *Two case studies*

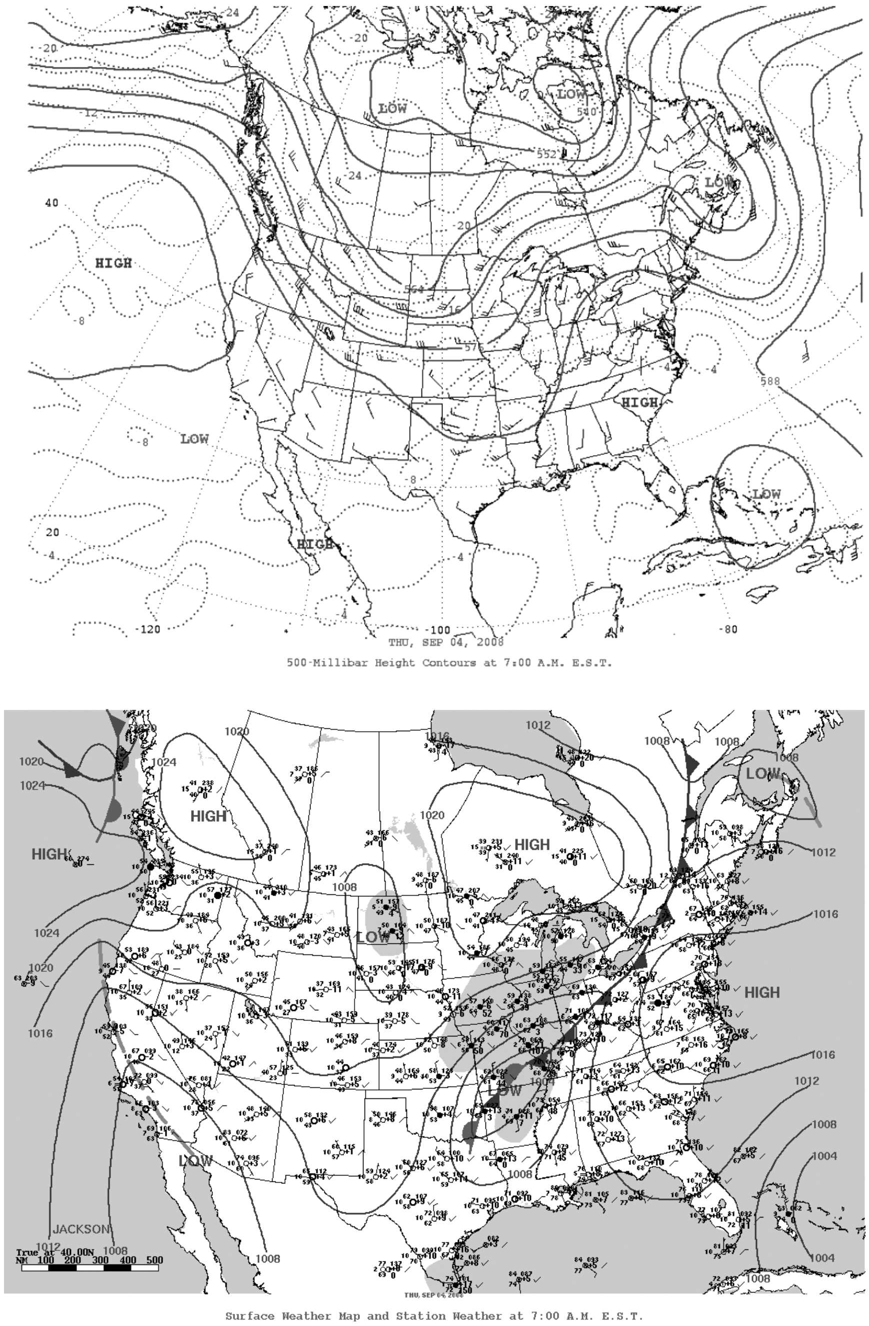
A particular set of events showed the importance of data in the network, the remnants of Hurricane Gustav and Hurricane Ike. There were many reports provided from the CoCoRaHS network of volunteer observers for each case. We will look at and compare data from the CoCoRaHS observers and the data from the National Weather Service Offices that were particularly affected by these disturbances.

a. Hurricane Gustav

The remnants of hurricane Gustav moved through the state during 3–4 September 2008. Rainfall amounts varied greatly in parts of the state, and the Midwest as Gustav became an extratropical system.

The remnants of Gustav interacted with a 500 hPa trough and a slow-moving cold front that merged with the remnant

Figure 2. The 500 hPa (top) and surface map (bottom) for 1200 UTC 4 September 2008.

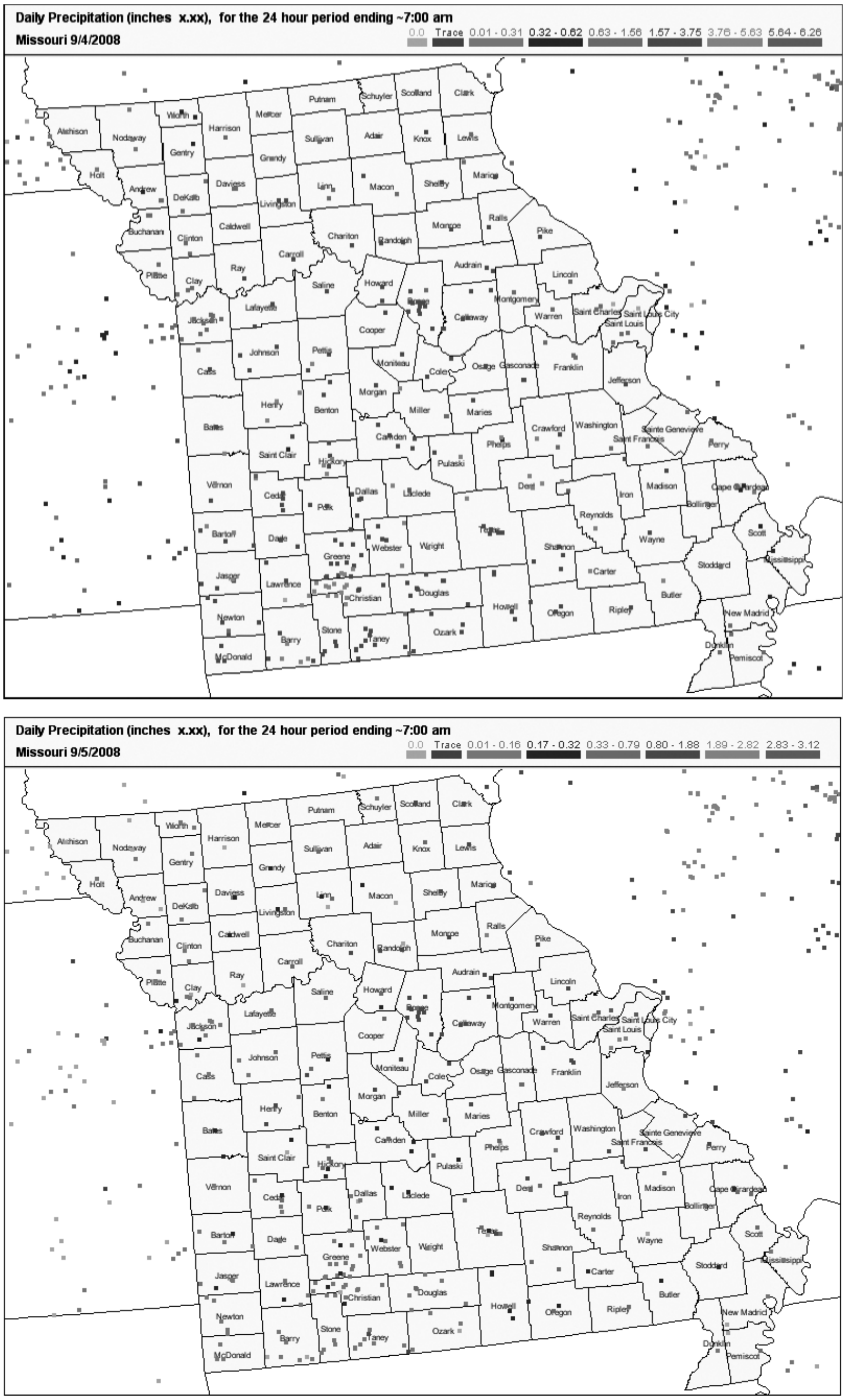


tropical depression (Fig. 2). The cold front aided in transitioning the tropical storm to an extratropical system (NWS EAX, 2008a). The remnants of Gustav induced a wave of low pressure on the frontal boundary (MRCC, 2008a). Additional evidence that the remnants of Hurricane Gustav were transitioning from a tropical storm to an extratropical system is shown in Fig. 3. Heavy precipitation is noted across both Missouri and Arkansas where Gustav merged with the cold front.

The heaviest period of precipitation occurred between 1900 LDT 3 September and 0700 LDT (1200 UTC) 4 September (NWS SGF, 2008a). Rain continued though 1200 UTC on 4 September 2008, thus, we can compare rainfall amounts for the 24-h period following 1200 UTC as well.

Figure 3 shows the observed values of rainfall from CoCoRaHS precipitation reports plotted on a county map of Missouri for the mornings of 4 and 5 September 2008. Note that the heaviest values on 4 September 2008 were found in the southwest part of the state and were on the order of three to six inches. The next morning, two to four inch rainfall amounts were found in the Saint Louis area. This can be compared to graphical data

Figure 3. The daily CoCoRaHs maps for 1200 UTC 4 September, 2008 (top) and 1200 UTC 5 September, 2008 (bottom).



showing amount of precipitation received across Missouri including the NWS storm radar estimates (Fig. 4) and Midwestern Regional Climate Center graphical data which used CoCoRaHS reports to compile the precipitation map (Fig. 5). Note that the total composite in Fig. 5 agrees well with the amounts shown on the two separate CoCoRaHS maps shown in Fig 3.

The data that were compiled from the NWS and the Midwestern Regional Climate Center all incorporated CoCoRaHS observation data. The use of CoCoRaHS reports and

Figure 4. The radar estimated one day precipitation (in) accumulations for approximately 1500 UTC 3 September to 1500 UTC 4 September, 2008.

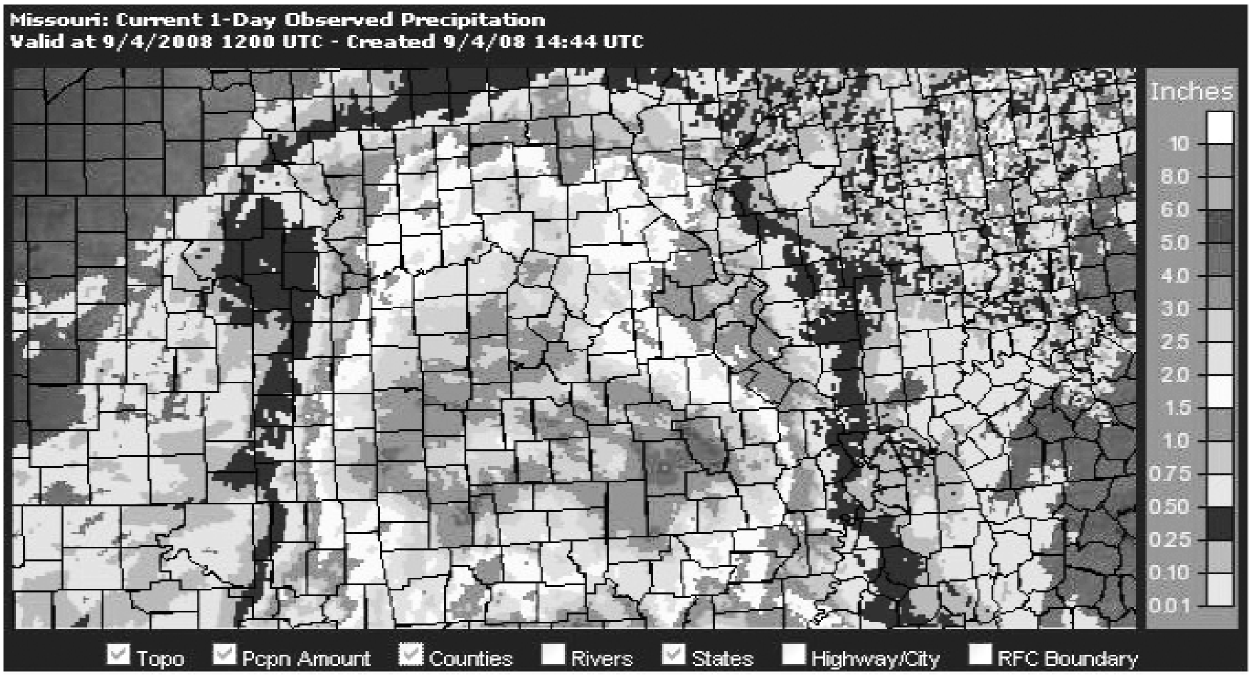
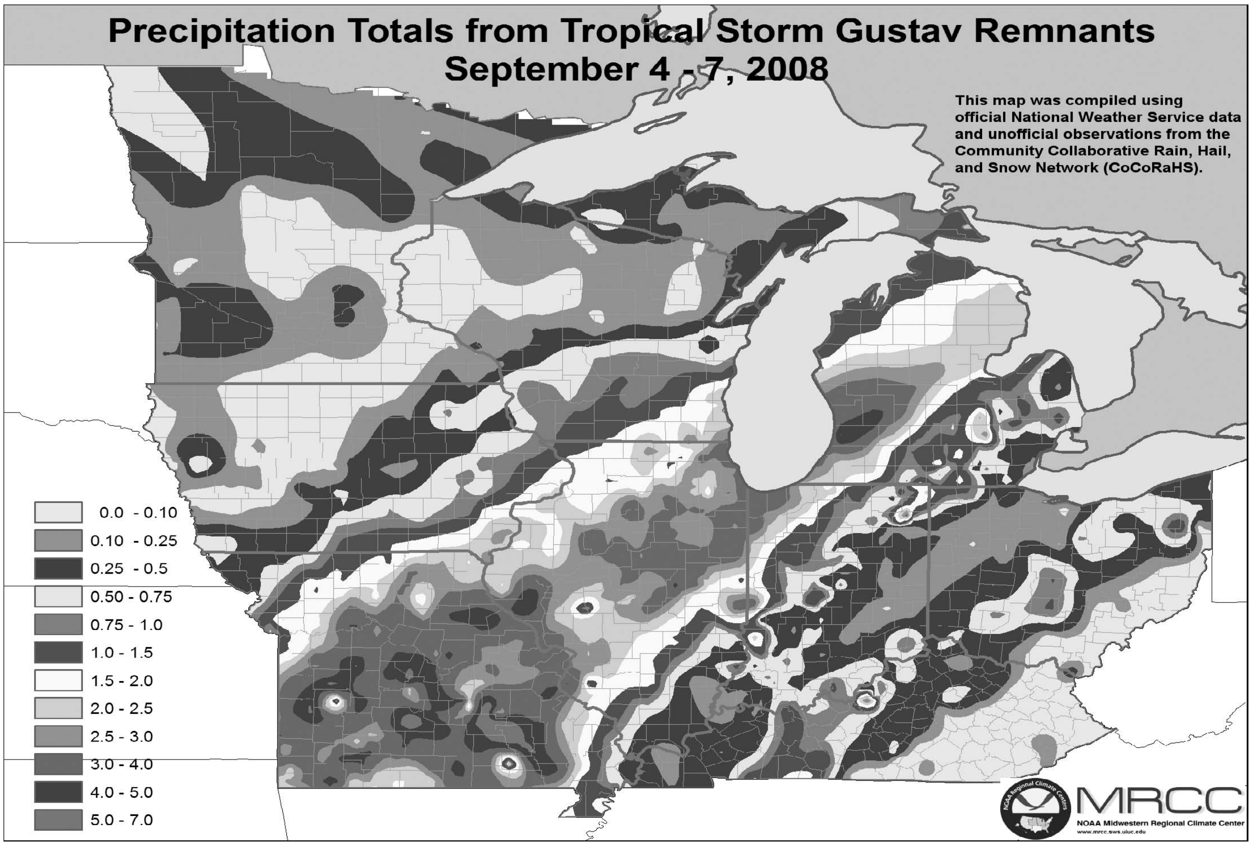


Figure 5. The composite total precipitation for the midwest for Gustav (taken from the Midwest Regional Climate Center — http://mrcc.isws.illinois.edu).



observations in this particular event is a strong indication that the data provided were indeed valuable and reliable.

b. Hurricane Ike

The second significant event to affect the Midwest during September 2008 was the remnants of Hurricane Ike. Hurricane Ike came ashore in Texas about 300 miles west of where Gustav did, but on 13 September, 2008. The storm moved through Missouri on 14 September, 2008 (Fig. 6). An examination of the 500 hPa and surface maps suggests the synoptic situation was very similar, including the presence of an upper air trough and a slow moving cold front approaching from the west. The remnants of Hurricane Ike had more moisture available to work with than the remnants of Gustav, as temperatures and dew points were 5–9° F (2.5–5° C) warmer across the state (Fig. 2

Figure 6. As in Fig. 2, except for 1200 UTC 14 September, 2008.

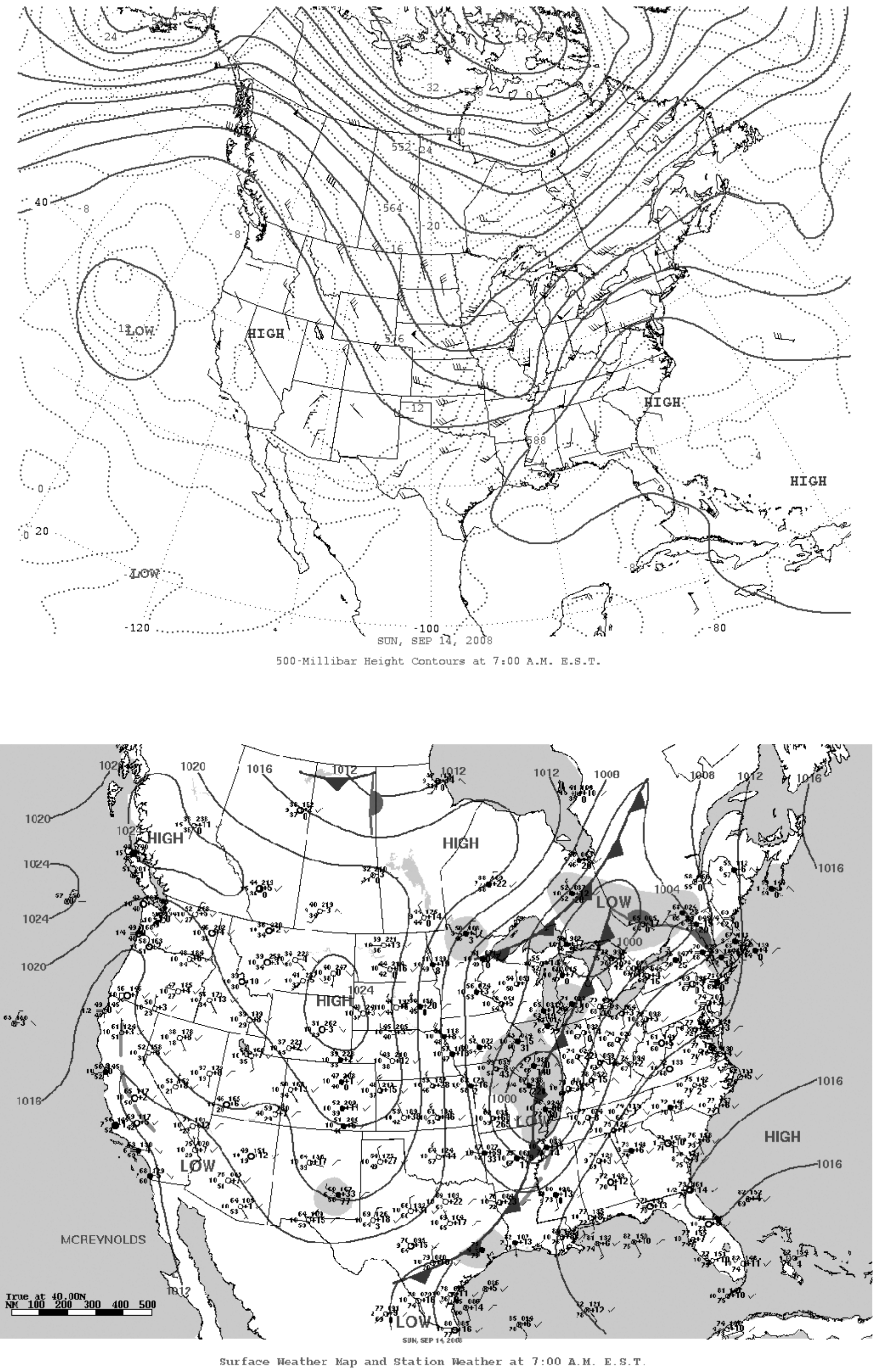
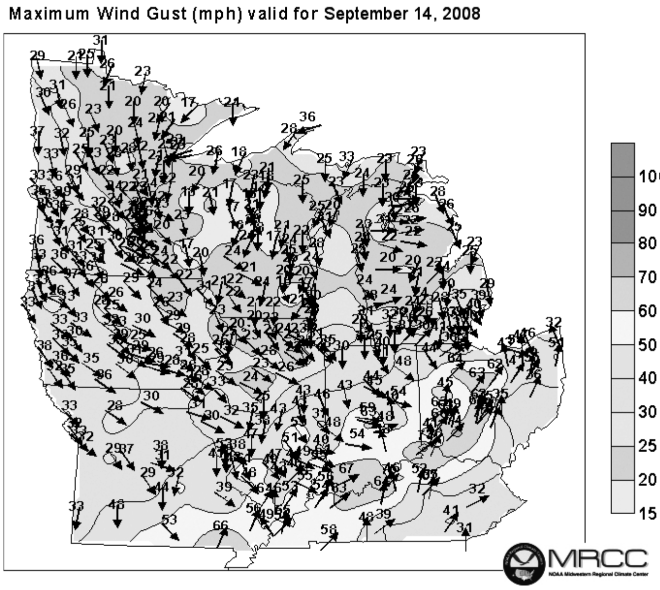


Figure 7. The maximum wind gusts across the upper midwest during 14 September 2009, and associated with the remnants of Ike (taken from the Midwest Regional Climate Center — http://mrcc.isws.illinois.edu).



and 6). There were some factors, however, with this disturbance that made Ike a more significant event than the remnants of hurricane Gustav. The remnants of Hurricane Ike were still classified as a tropical storm throughout Southwest Missouri to very near the city of St. Louis (Fig. 7 and http://www.nhc.noaa.gov/tracks/2008atl.jpg). The system would interact with an upper air vorticity maximum later (not shown), which would re-invigorate the storm as a strong extra-tropical cyclone with winds up to 80 mph in Ohio.

The observers from CoCoRaHS were ready to help especially since the remnants of Hurricane Gustav occurred just 9 days earlier. As describe above, one of the major factors in the excessive rainfall produced by the remnants of Hurricane Ike was a cold frontal boundary draped across the Missouri region (NWS EAX, 2008b). The cold front acted as a lifting mechanism for the likely enhancement of thunderstorm development during 13 September, 2008 (Fig. 8), and the rainfall was greater with this front that the one associated with Gustav. The abundance of moisture produced by the remnants of Hurricane Ike combined with the frontal boundary. This added to the unusually high amounts of rainfall. (Figs. 9, 10)

The stronger remnants of Hurricane Ike were clearly visible on RADAR with an eye-like feature noted in the image of 0600 UTC 14 September, 2008 (Fig. 11). The strength of the disturbance was great enough to produce several EF-0 tornados in eastern Kansas and west central Missouri (NWS SGF, 2008b, MRCC, 2008b). Strong wind gusts caused power outages around St. Louis County (NWS LSX, 2008). The storm also produced copious amounts of rain and caused wide-spread flash flooding and river flooding events (NWS LSX, 2008). The storm claimed three lives in Missouri. Damaging winds were reported as far north as upstate New York.

Before the arrival of the remnants of Hurricane Ike the atmosphere indicated precipitable water values as high as 2.20 inches. Climatologically, the water content of the atmosphere was greater than two standard deviations above normal for July (NWS EAX, 2008b). There were also many locations from southeastern Kansas to central Michigan that received upwards of 7 inches of rain (Fig. 10).

Figure 8. As in Fig. 4, except for 1200 UTC 12 September to 1200 UTC 13 September, 2008.

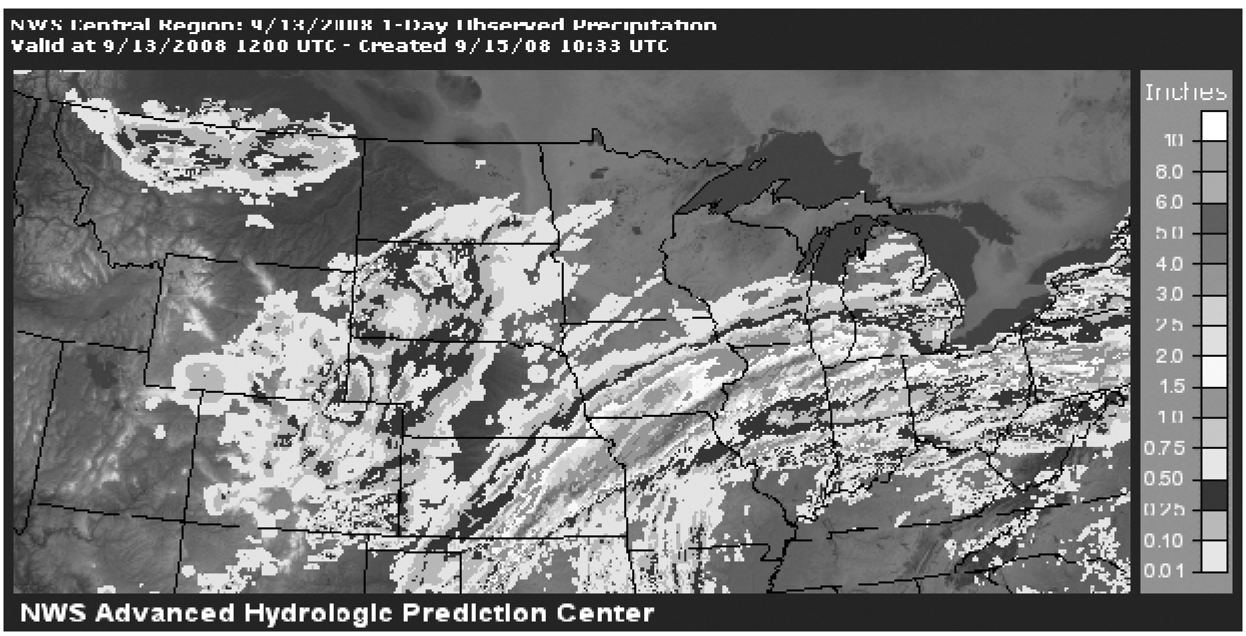


Figure 9. As in Fig. 4, except for 1200 UTC 13 September to 1200 UTC 14 September, 2008.

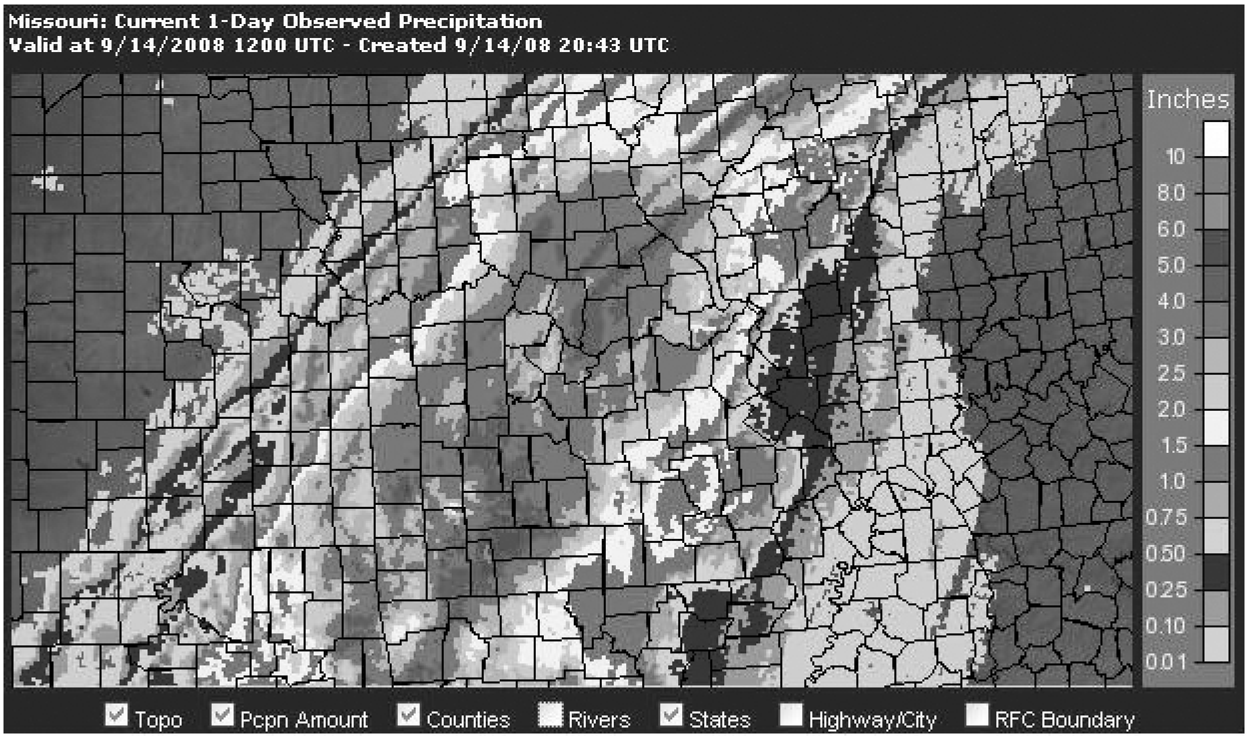


Figure 10. As in Fig. 5, except for 12–15 September 2008.

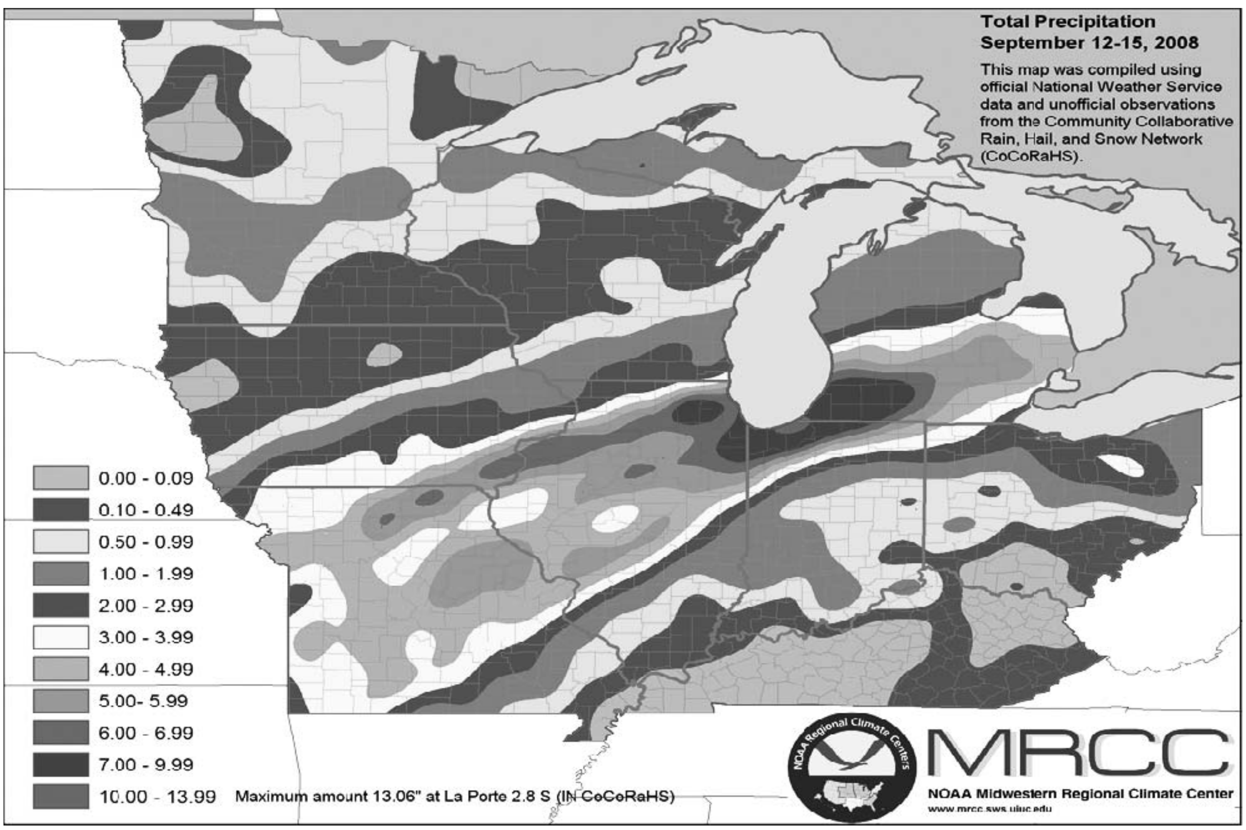
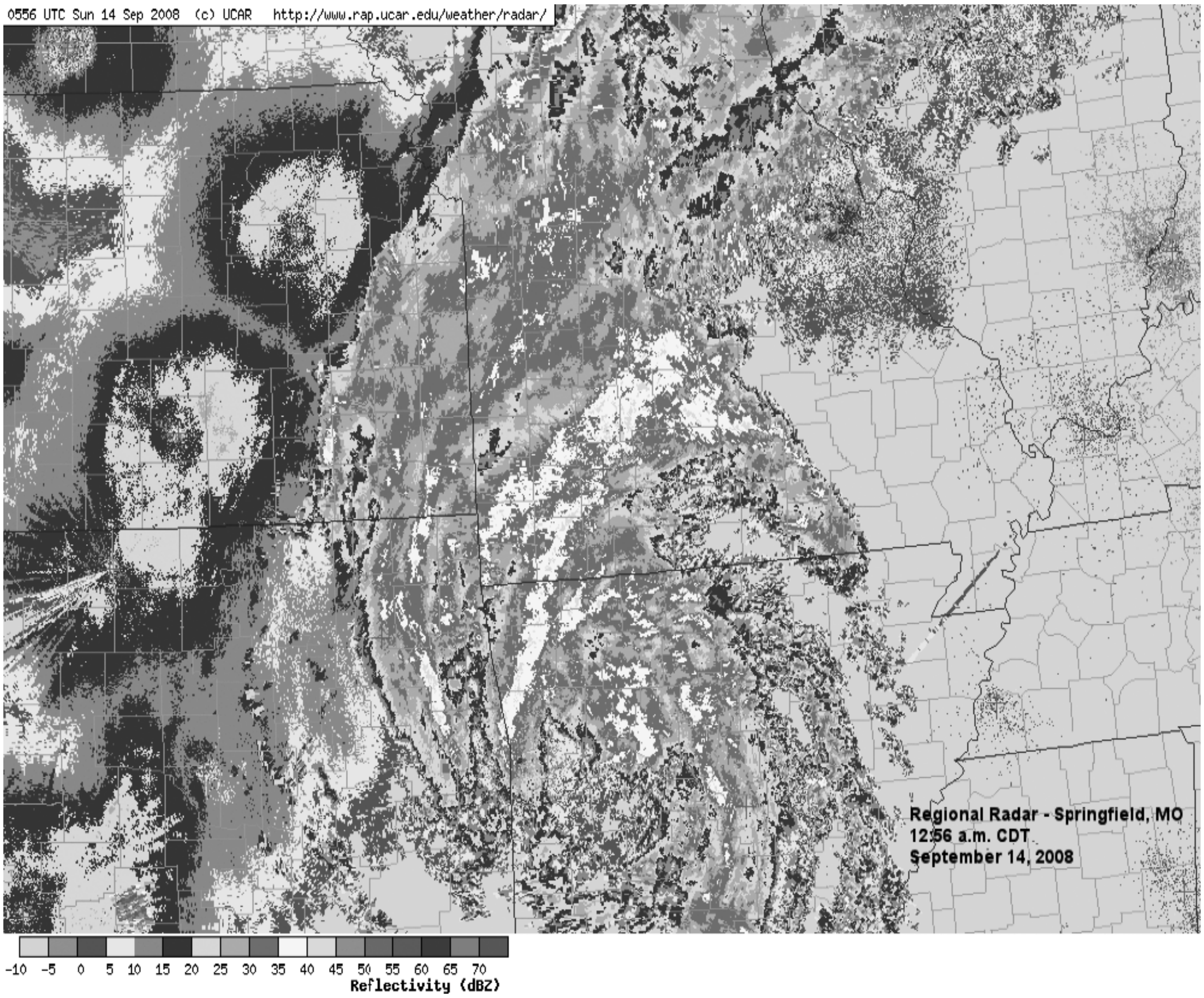


Figure 11. The radar image from the Springfield, National Weather Service Office from 0600 UTC 14 September, 2008.



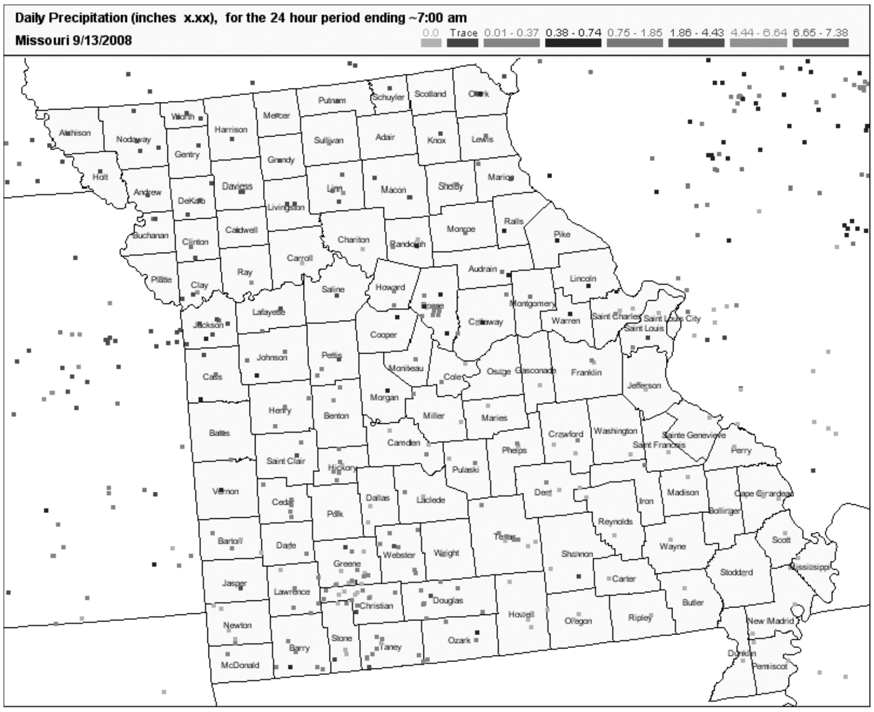
The Missouri CoCoRaHS network was a valuable tool in assessing rainfall reports throughout the state of Missouri for this particular event. The CoCoRaHS data were incorporated in the storm reports for NWSFOs with County Warning Areas in Missouri. The data from radar rainfall estimates and reports from coop observers, automated systems produced a great amount of information for the significant weather event. It is noted here that all of this information is collated into the graphical products produced by the NWS. The CoCoRaHS reports (Fig. 12), are congruent with the values shown in these products (Fig. 9). It should also be noted that inadequate RADAR coverage in places such as northeast Missouri may yield poorer estimates and can be augmented by the other types of data discussed above and CoCoRaHs data.

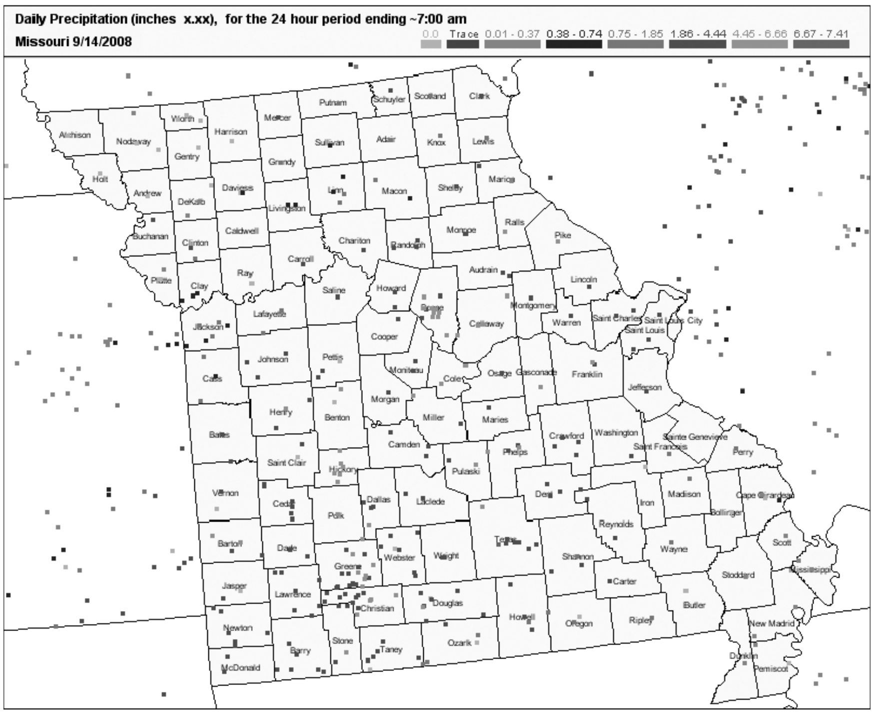
4. Summary and Conclusions

The CoCoRaHS network reports all forms and types of precipitation, rates of precipitation, and special occurrences happening at time of observation and can be reported. The CoCoRaHS data and reports show the general areas of precipitation amounts, but may also focus on individual county or metropolitan rainfall amounts. This kind of finer detail can be used in more detailed studies than those performed here, as information such as this is imperative to understanding and analyzing these complex weather phenomena occurrences from a mesocale view all the way down to a microscale view. This is where CoCoRaHs data has the most potential for use.

A cursory synoptic examination of the remnants of hurricane Gustav and Ike demonstrated that volunteer precipitation measurements are as consistent and accurate as those measured from professional observers, automated rain gauges and even higher order technology such as radar derived precipitation estimates. NWS (personal communication) personnel have noted some errors in CoCoRaHs data. However, some offices are able to quality control the data, and the state coordinators also perform quality control. Thus, CoCoRaHS information demonstrated reliability as a method for providing ground truth for future improvements of radar techniques.

Figure 12. As in Fig. 3, except for 1200 UTC 13 September (top), and 1200 UTC 14 September 2008 (bottom).





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