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Emerging Technologies in the Field to Improve Information in Support of Operations and Research

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ABSTRACT

Over the past 50 years, mobile storm observers have proven to be a tremendous asset in furthering the meteorological understanding of severe storm behavior and characteristics, and they are an enhancement to the warning decision process in local National Weather Service forecast offices. New technologies are providing innovative ways to complement mobile storm spotting. This paper examines three prominent emerging technologies: the Spotter Network, the Mobile Rapid Environmental Sampling System, and Live Chase Cams. These tools provide real-time applications for severe weather reporting, dissemination of data collected *in situ*, field coordination, mesoanalysis, warning decision making, and quicker dissemination of relevant information to the public. A vision of the development and integration of these technologies is described and discussed.

1. Introduction

Over the past half-century, mobile storm observers in the field have helped revolutionize our understanding of severe storm behavior and characteristics (Doswell 2007). This was at least partially accomplished through the use of visual observations and new innovative technologies. Severe weather reports from researchers and storm hobbyists, in addition to trained SKYWARN

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volunteers, have long provided a significant enhancement to the warning decision process in local National Weather Service (NWS) forecast offices.

Advances in technology over the past decade, specifically the widespread availability of low-cost internet access via cell phone and broadband cards, allow storm observers an unprecedented opportunity to support both the operational and research communities with real-time information. This is especially evident in rural areas common to the American Great Plains, where very low population densities tend to limit the flow of real-time information. This paper examines three prominent, emerging technologies: the Spotter Network (SN), the Mobile Rapid Environmental Sampling System (MRESS), and Live Chase Cams (LCC). These tools provide viable venues for severe weather reporting, dissemination of data collected *in situ*, field coordination, mesoanalysis and warning decision making. The paper also focuses on technologies for individuals with interests in severe weather reporting, mobile weather observations, and streaming video. The development and integration of these is discussed.

2. Equipment

A mobile storm observer's equipment varies based on individual need, financial ability, and purpose. A generalized outline of equipment and flow of information is provided in Figure. 1. The backbone of most field applications begins with a laptop computer, which has become relatively universal among storm observers. A global positioning system (GPS) has become standard for improved road navigation while in the field. Internet access is frequently obtained in the field by connecting a cell phone to a laptop, broadband wireless cards, or a satellite internet provider. Regardless of the method to acquire internet access, the mobile connection serves as the framework to collect and disseminate information in real-time applications.

3. Technologies

a. Spotter Network

The Spotter Network (SN) was created by AllisonHouse LLC as a free service and introduced to the public in early 2006 (found online at http://www.spotternetwork.org). SN brings storm spotters, storm chasers, coordinators, and public servants together seamlessly. SN provides highly accurate positional data on storm observers for coordination and reporting purposes, and delivers 'ground truth' information to public servants. The network is designed to improve the flow of real-time information without taxing human resources, both in the field, and in NWS offices where meteorologists utilize this information.

As discussed by Pietrycha and Fox (2004), the mobile spotter/chaser contingent has proven to be a fantastic resource for real-time severe weather reporting, and yet, is often underutilized due to ineffective communication between the mobile storm observer and the NWS. This is particularly acute in NWS county warning areas containing low population densities. The SN helps greatly to fill the communication gap and utilizes the NWS eSpotter program, at no cost to the SN participant or the NWS.

The SN allows a storm observer to report several types of hazardous weather information through a SN graphical user interface on a personal computer (Table 1), or Internet enabled phone. Testing shows the report received through eSpotter, at participating local NWS offices, arrives in less than 45 s from original submission to the SN. SN participant locations and reports can be monitored through the SN website and several software clients including GRLevelX (Fig. 2), Google Earth, NWSChat, and through Really Simple Syndication (RSS) readers to name a few.

In each of the interfaces, NWS personnel can monitor SN participant locations and query them through the supplied contact information to assist in the warning decision process. Additionally, field coordinators responsible for research teams can utilize SN to monitor the location of pertinent vehicles relative to the investigated feature and quickly report hazardous weather via the SN. Note, with SN it is possible to establish 'privacy settings' whereby research teams can select who is allowed to monitor their field operations.

Presently, not all NWS offices use the same severe weather criteria. As such, the SN reporting thresholds were purposely selected to satisfy the widest range of recipient needs (Table 1). Note the last four criteria have a qualifier of "in relation to severe weather" since the SN is designed to be real-time severe weather related. Reports such as rainfall amounts in the past 24 hours are not appropriate, unless it coincides with severe weather criteria.

Reports sent to the SN are closely monitored and 'policed' in an effort to maintain the highest quality of information. Beginning in 2009, several measures have been implemented and are summarized below:

- Completion of an online basic severe weather training program is required for all SN members before reporting capability is allowed.

- All reports are logged and the SN is investigating the implementation of a phone number verification system. This is primarily to mitigate false reporting by people who believe they can remain anonymous.
- The SN Advisory Committee conducts after-the-fact report quality control reviews of all reports.
- The SN does not tolerate any false severe weather reports or false position reporting. If such activity occurs the reporting person is permanently banned from the SN upon first offense.

SN has provided one of the first opportunities to accurately quantify severe weather reports, as all reports are tracked, archived, and reviewed. At this time, there are ~5,500 registered participants in the SN. Registration is not required to view reports so the actual use of the SN data is significantly higher. From 1 January 2007 through 31 December 2008, more than 2100 reports were sent through the SN (Fig. 3). More than 700 met severe criteria (tornado, hail diameter $\geq$1.9 cm, wind $\geq$ 25.9 m s^{-1}) and were also ready for Local Storm Report (LSR) issuance by the NWS. An additional 800 reports were for supplemental non-severe information (wall cloud, funnel cloud, outflow-dominant state). Furthermore, 536 reports were sent for winter weather, flash flooding, and excessive rainfall.

A distribution of normalized SN reports by month shows, not surprisingly, a reporting maximum in May and June (Fig. 4). This is traditionally the peak period of mobile storm observers collocated within a high frequency of severe weather occurrence across the central contiguous United States (CONUS). A distribution of SN severe reports differentiated by tornado, hail, and wind shows a relatively similar breakdown by year and event type (Fig. 5). The central CONUS contains an overwhelming number of SN reports as shown in Figure 6a-b. Based on these data, it is apparent large concentrations of mobile storm observers frequent the central CONUS. This population of mobile observers is extremely valuable to the warning decision process.

b. Mobile Rapid Environmental Sampling System

The Mobile Rapid Environmental Sampling System (MRESS) was introduced in early 2008 as a means to collect, disseminate, and archive mobile weather observations in real-time (found online at http://www.mress.org). MRESS is a software system designed to collect and stream data from multiple remote and *in situ* sensing platforms to a central server for archive and dissemination, via a real-time, graphical user interface and placefiles. The system envisions incorporating governmental and university research groups, private individuals, public servants, and others that utilize mobile scientific-grade instrumentation similar to mobile mesonet (MM) standards (Straka et al. 1996). These data are distributed in real-time through one location as a means to support operational meteorologists in mesoscale analysis and the warning decision process.

In order to be compatible with MRESS, a participant has some or all of the basic surface observation instruments with scientific-grade quality. This translates to a high level of confidence in data quality for operational meteorologists monitoring and incorporating these observations into analysis and decisions. Observations from the MM vehicle are processed and transferred through the internet via cell phone, Wireless Fidelity (WIFI), or satellite connection to a central data repository server. A graphical MRESS outline is provided in Figure 7. Data are available immediately from the MRESS website or supplemental placefiles viewable in software applications such as GRLevelX and RSS viewers. The placefile retains a 20-minute trail of observations and eliminates clutter as observations appear and/or disappear depending on the desired domain and resolution of the user. Archived one-minute observations can be viewed in graphical format or supplemental placefiles through the MRESS repository server interface where users request specific days and times of data.

A single MM based in Norman, Oklahoma tested the MRESS during the spring months of 2008. As depicted in Figure 8, various software clients displayed the meteorological data collected by the MRESS in real-time. Several NWS forecast offices monitored these data in real-time during convective warning operations. The observations provided forecasters *in situ* data for storm-scale associated features. Furthermore, due to the research-grade equipment used for the MM, forecasters had high confidence in the validity of the data.

One interfacing capability of MRESS is to send MM location and severe wind measurements automatically to the SN. The system performs a rapid analysis and quality control of wind gusts, which are grouped and forwarded to the SN within seconds of detection by the remote system. Figure 9 demonstrates an example of severe wind gusts encountered in the rear-flank downdraft of a supercell thunderstorm on 23 April 2008. Wind speeds peaked at 35 m s^{-1} and resulted in significant damage to power lines and poles. The utility of MRESS sending an automated report via the SN allows for rapid dissemination of information with greater accuracy.

Although MRESS began with a single unit, the system is designed to support thousands of mobile observing systems. With a unique extensible communication system and data storage design, future expansion of the MRESS should require minimal effort. The largest challenge to expanding the numbers of vehicles housing mobile weather observations is the expense of scientific-grade instrumentation. It is speculated the relatively high costs have contributed to low numbers of private individuals involved in MRESS thus far. The system provides the research community an opportunity to disseminate quality, real-time surface observations to the operational community by utilizing existing MM platforms during ongoing field projects at no cost through MRESS.

c. Live Chase Cams

Increased band width has led to a growing popularity of web-based "weather cams" over the past decade. The live chase cam (LCC) process allows individuals in the field to broadcast imagery in real-time to a designated location on the internet. A video camera typically mounted to the vehicle dashboard feeds into a laptop computer where software encodes the data. The encoded video data is then shipped through the internet to the designated web page.

A wide spectrum of businesses, agencies, schools, and individuals (state parks, media, transportation departments, and private residencies) have installed cameras available for public usage. Occasionally, these web cameras serve as an effective tool in support of operational meteorology, such as monitoring convective initiation, storm structure, or snowfall rates. Unfortunately, web cameras are typically confined to populated areas, remain in a fixed position, and transfer only static images. The last decade also brought intense media competition for weather coverage in a few CONUS regions. Today, in larger television markets where fast-breaking weather is frequently newsworthy, fleets of media vehicles and helicopters are deployed by television stations to transmit both still imagery and live video of ongoing convective weather. Still, this type of aggressive weather coverage does not represent the majority of media markets. For locations such as the rural Great Plains, the opportunity for a real-time view of convective weather has been rarely present during warning operations.

A strong emergence of live streaming video via the internet by storm observers was noted in 2008. Several NWS weather forecast offices monitored these tools in support of severe weather operations (Fig. 10). Monitoring the live feed is free and most frequently compatible with Windows Media Player or Silverlight. With the large number of storm observers streaming live video of ongoing severe convection, an operational forecaster now has the opportunity to visually observe severe storm morphology in real-time. LCC serve as the ultimate ground-truth tool during the warning decision process by providing real-time visualization of storm features and mitigating questionable or insufficient reporting issues.

4. Summary

The SN, MRESS, and LCC are emerging technologies, operated by storm observers, which have shown great potential in supporting the NWS warning decision process. These tools are available to monitor at no cost to the NWS or individuals in the field. The technologies are available to use and monitor during all times of the year. This is especially true during high-impact events found during the peak severe weather months when large numbers of highly experienced storm observers are present. Individuals monitoring these data can incorporate the tools into one situational awareness display through the use of placefiles in GRLevelX or RSS display programs. The tools provide surface observations, severe reports, and visual confirmation of ongoing weather, aiding in revolutionizing the methods of obtaining ‘ground-truth’ information in real-time. Local NWS weather forecast offices must choose to embrace these emerging technologies and dedicate the necessary resources to sufficiently monitor the existing wealth of information. Ultimately, the partnership bridge these technologies provide between field-based storm observers and the NWS will continue to enhance the warning decision process and increase the flow of relevant real-time information to the public.

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Figure 1. Outline of equipment and accessories utilized by some storm observers providing real-time data to field coordinators and operational meteorologists.

Table 1. SN accepted reporting criteria

• Tornado, Wall Cloud, Funnel Events
• Wind Speeds and/or Gusts ≥ 50 mph
• All Hail Events
• All Hydro Events in relation to severe weather
• All Winter Events in relation to severe weather
• All Tropical Events in relation to severe weather
• All Notable Damage in relation to severe weather

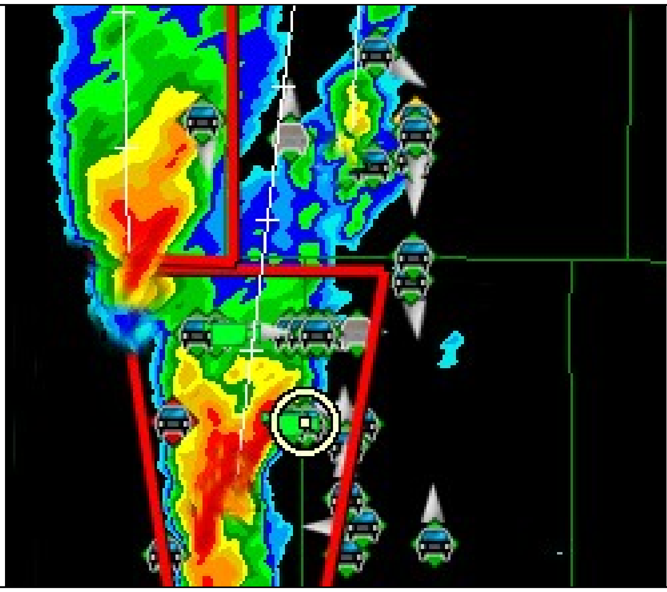

Figure 2. Example of SN as a placefile with GRLevelX software on 22 May 2008. A mobile storm observer is depicted by the diamond-shaped vehicle icon. A white carrot denotes the direction of movement of the SN participant.

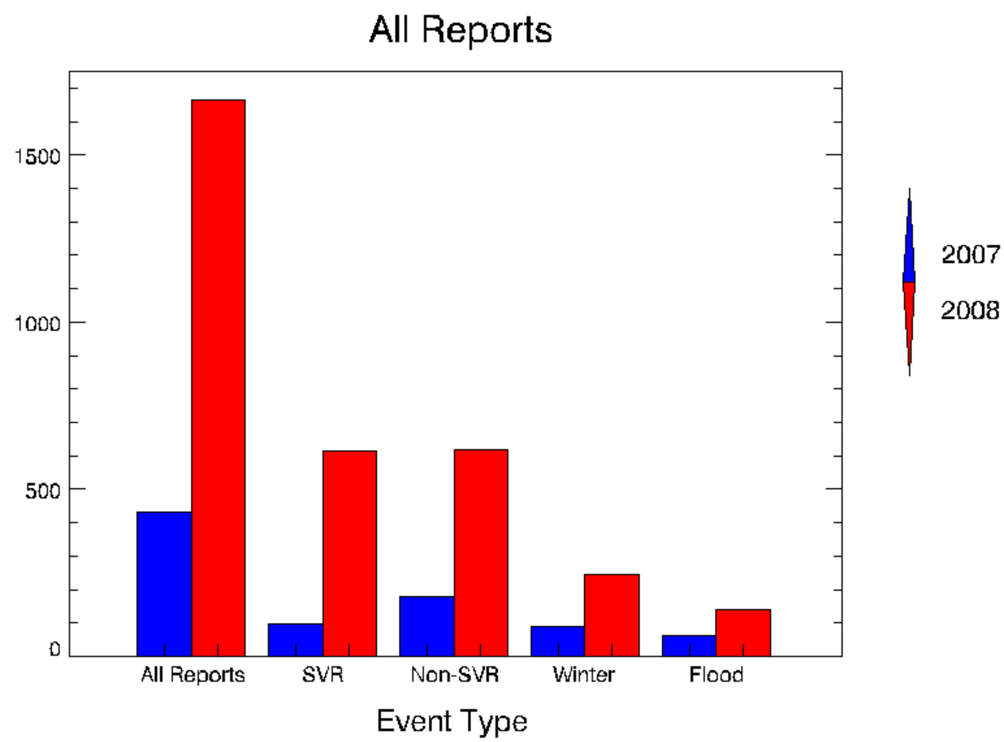

Figure 3. Distribution of all SN reports during 2007 (blue) and 2008 (red).

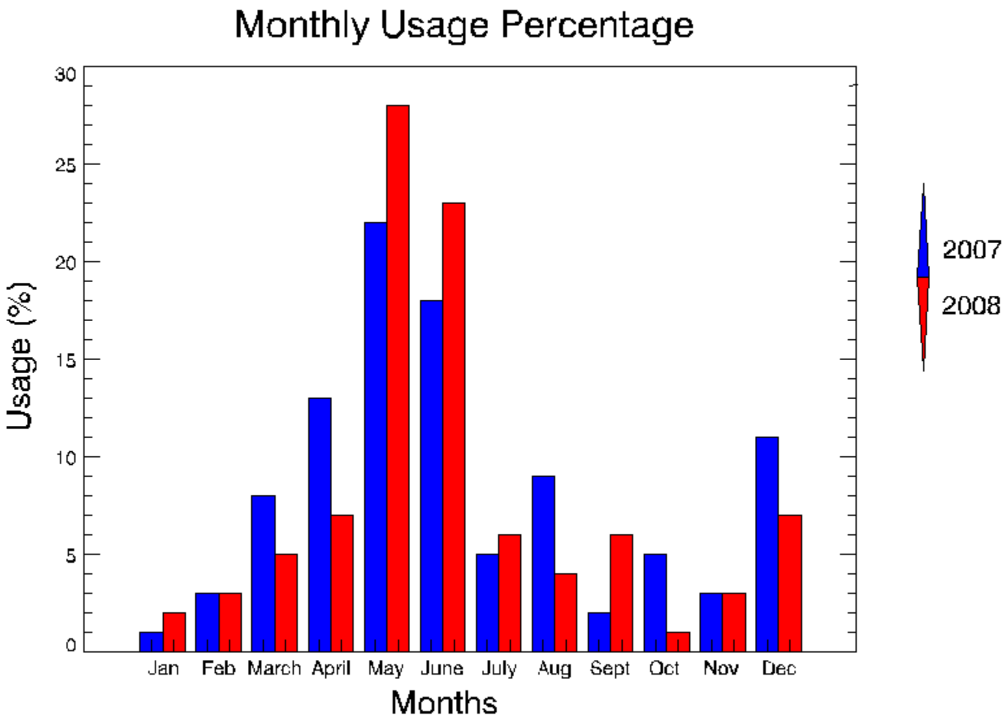

Figure 4. Normalized distribution of all SN reports by month during 2007 (blue) and 2008 (red).

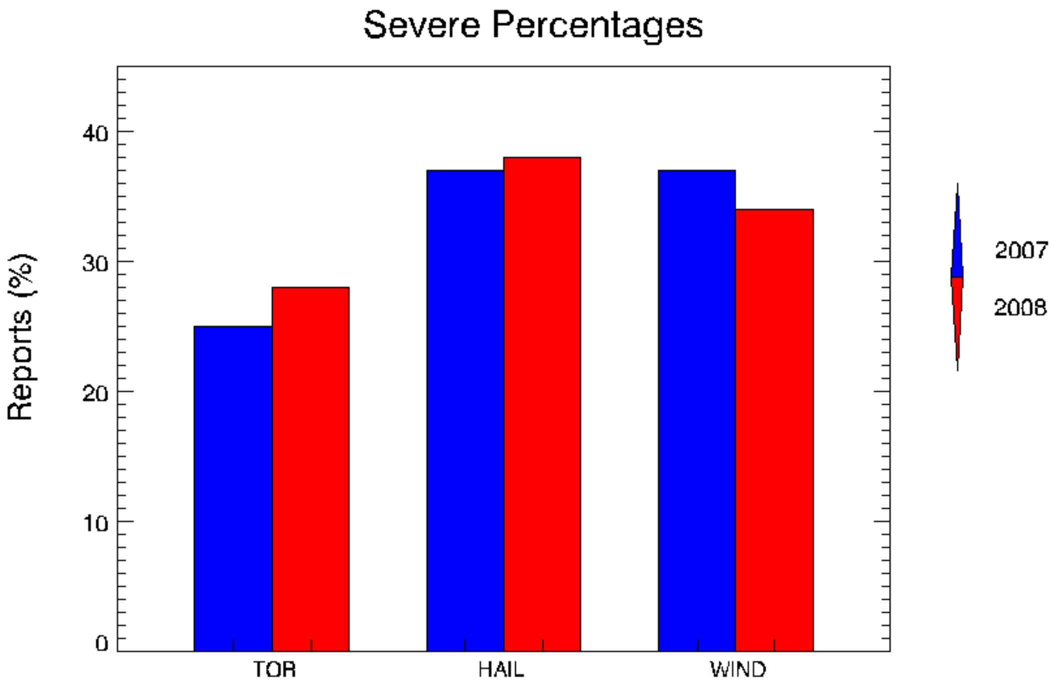

Figure 5. Percentage distribution of severe SN reports during 2007 (blue) and 2008 (red).

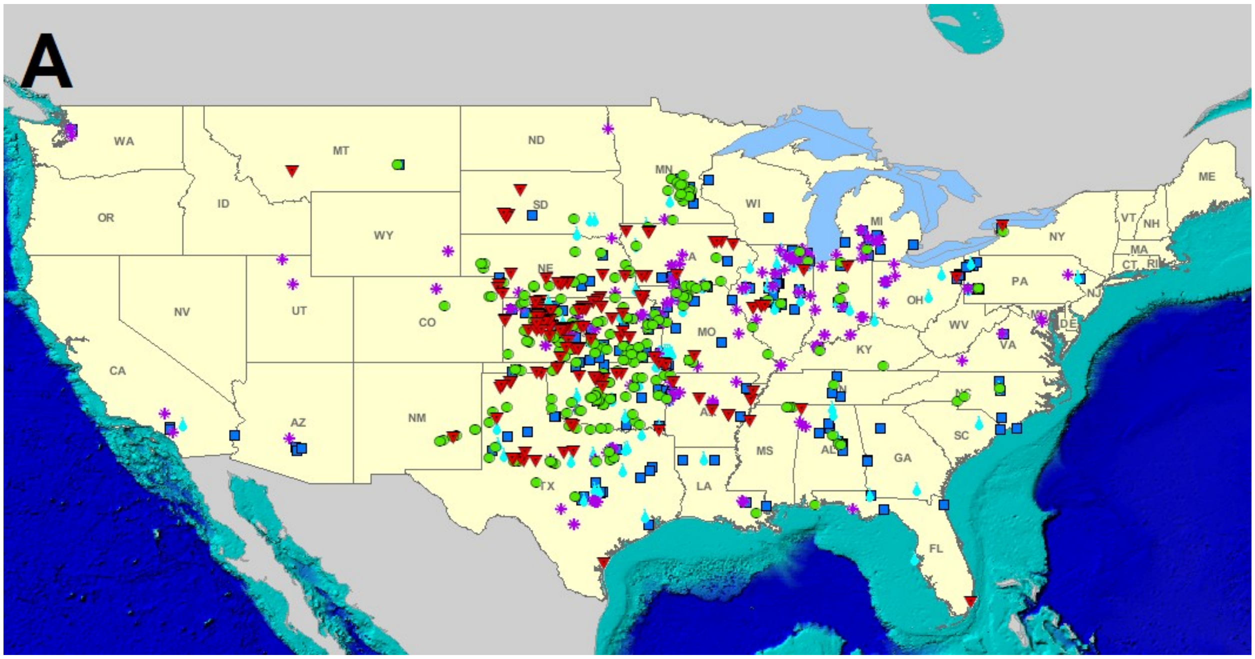

Figure 6a: Distribution of SN reports across the CONUS during 2007 and 2008. Reported tornadoes (red triangle), hail ≥ 0.75 in (green circle), wind speeds ≥ 58 mph (dark blue square), flooding (teal water drop), and winter storms (purple asterisk) are shown.

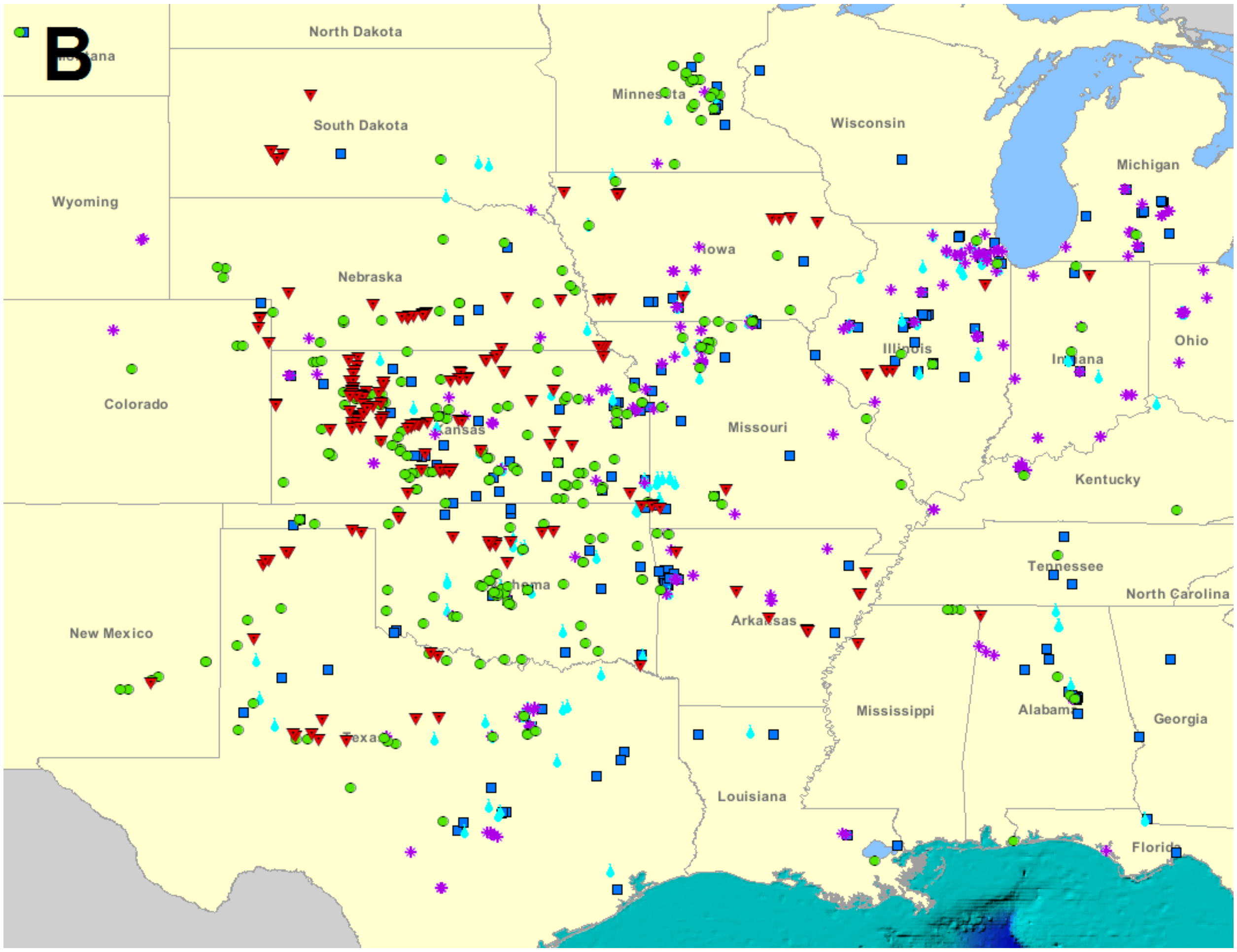

Figure 6b: Same as in Fig. 6a except for the central CONUS.

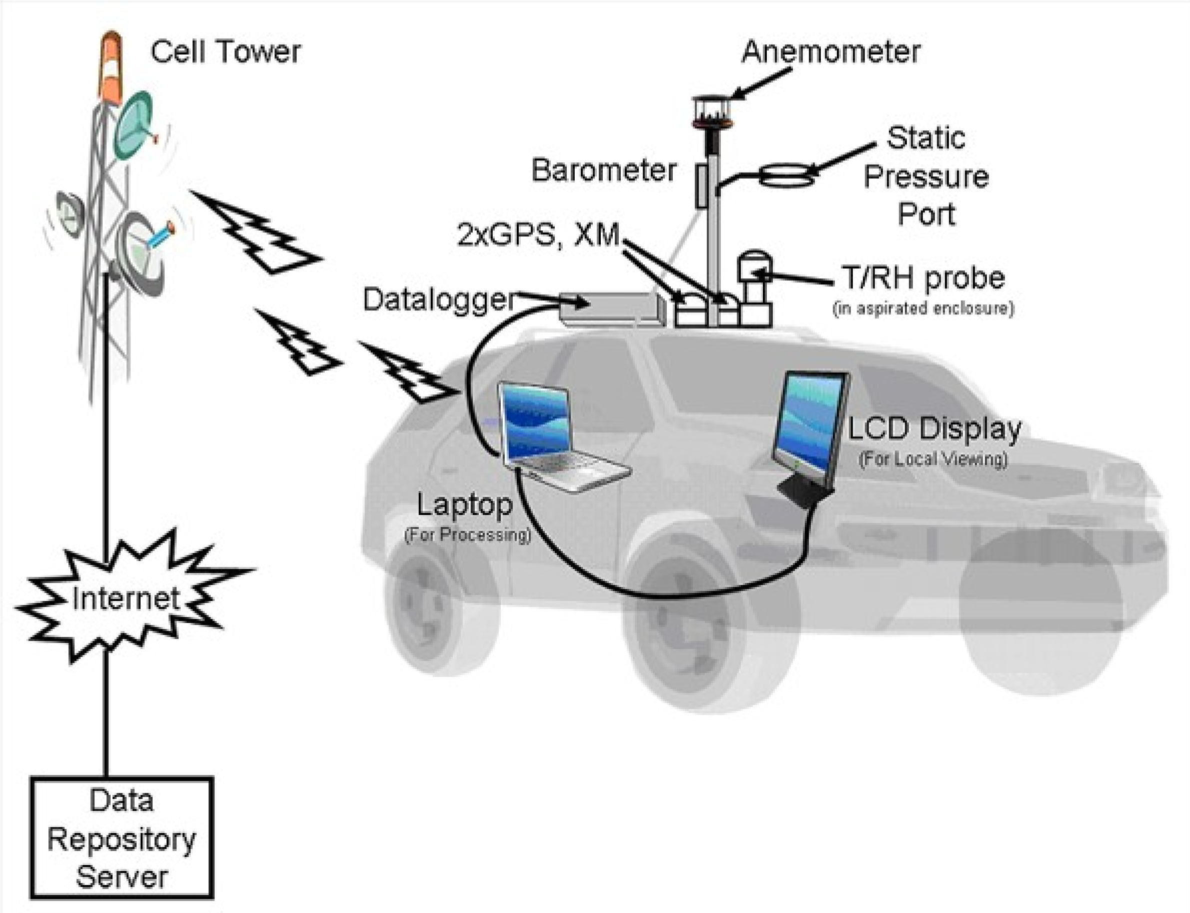

Figure 7. Overview of a basic MM vehicle implementing MRESS technology.

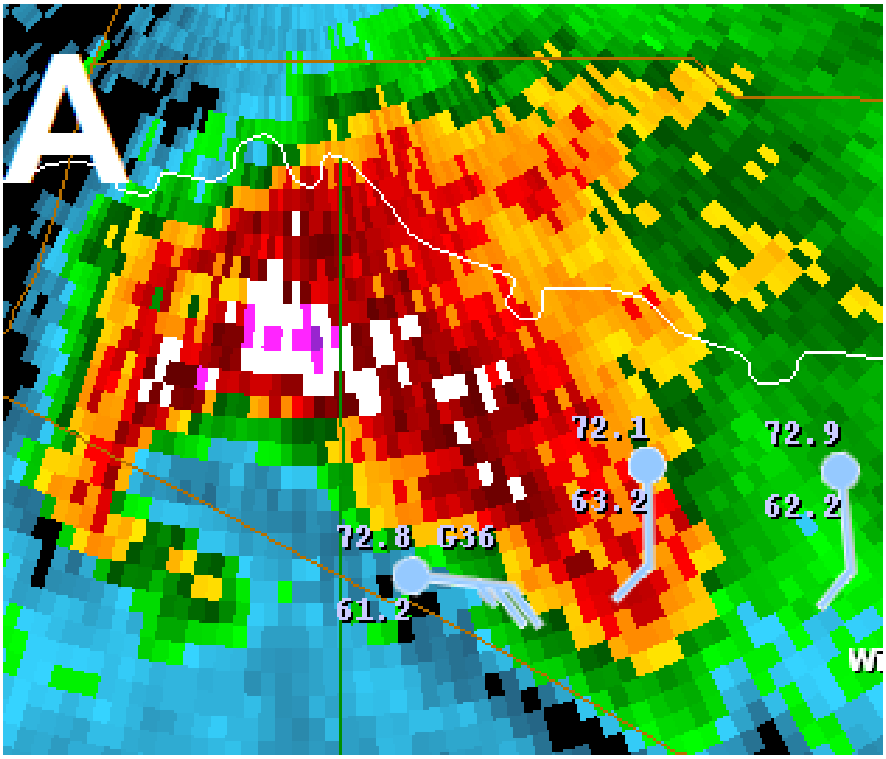

Figure 8a. Example of MRESS as a placefile with GRLevelX software on 7 April 2008. A wide view is shown. Standard station model depicted; temperature and dewpoint (°F), and winds (half barb = 2.5 m s^{-1}, full barb = 5 m s^{-1} mph).

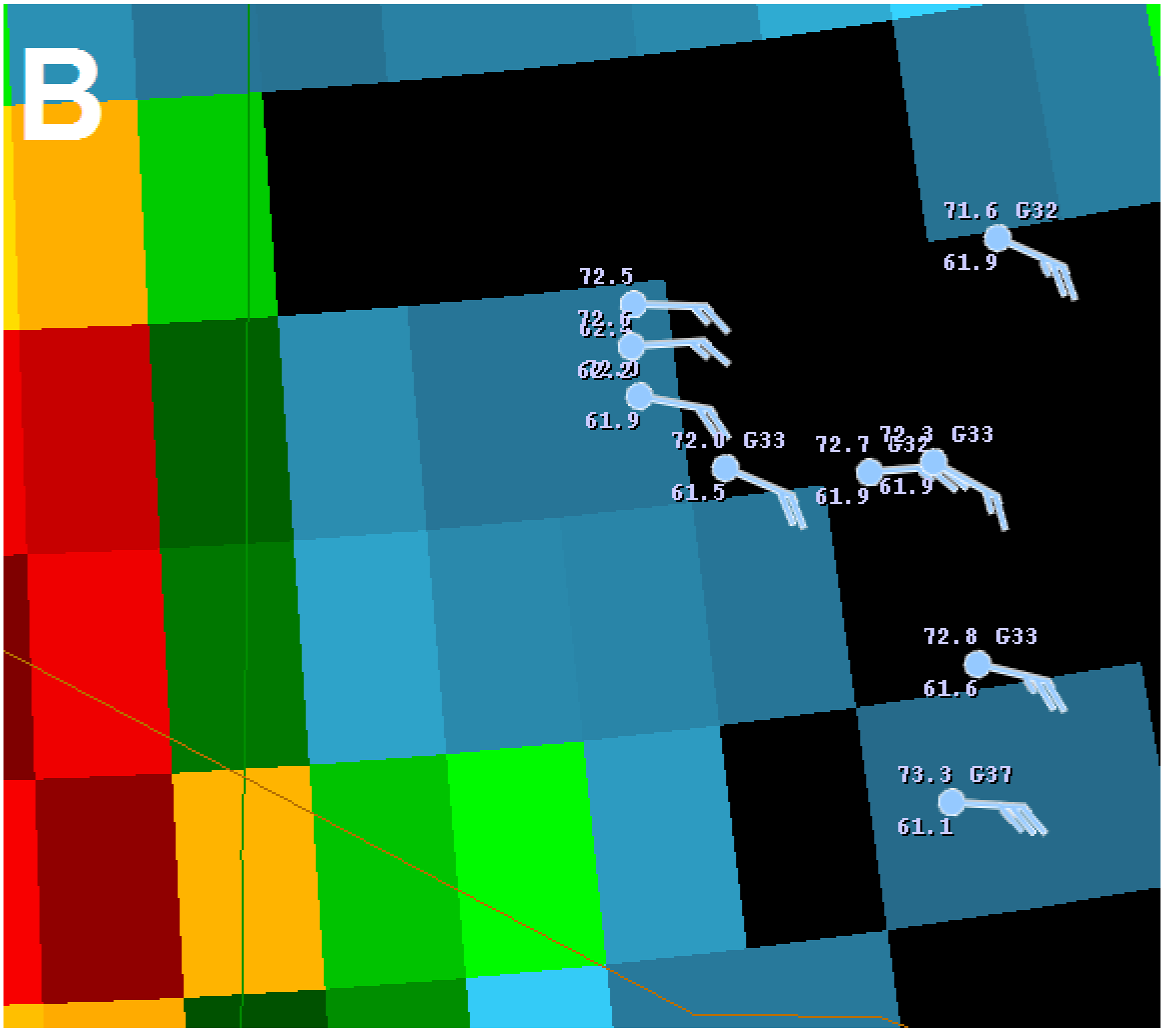

Figure 8b. Same as in Fig. 8a except showing a zoomed view into the inflow notch of a supercell thunderstorm.

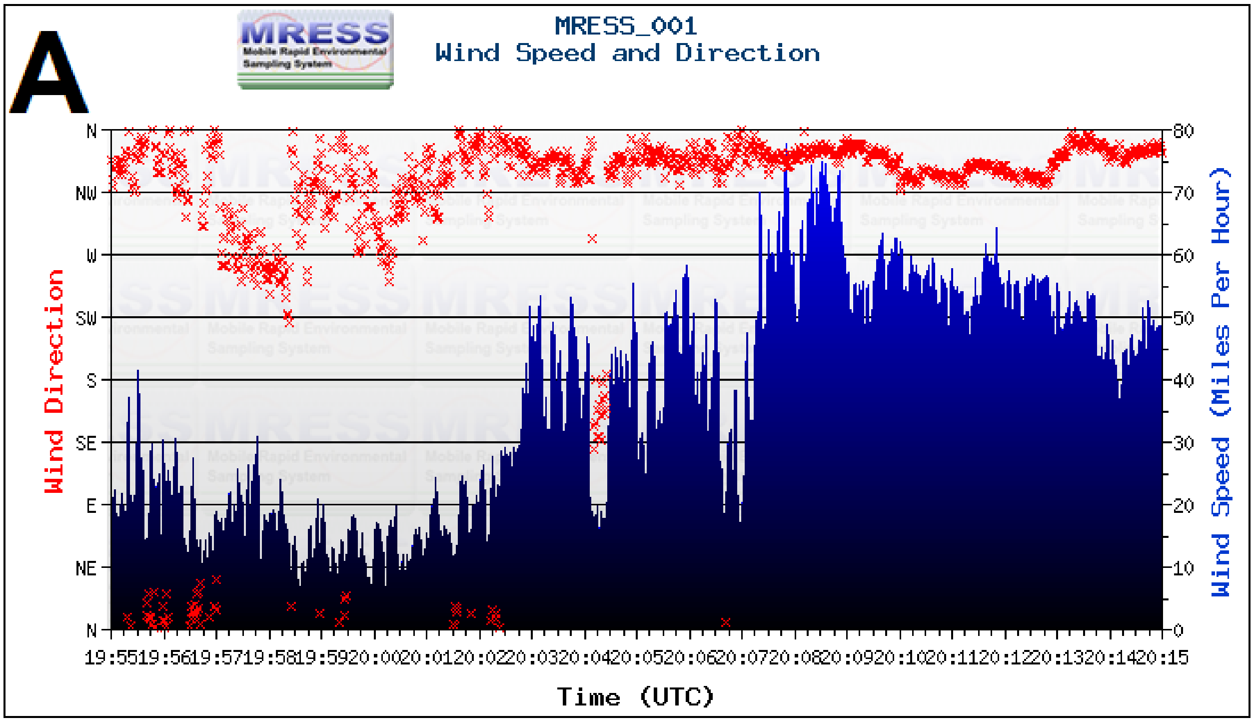

Figure 9a. MM vehicle utilizing MRESS during severe winds on 23 April 2008 near Snyder, TX. The trace shows measured wind speed (mph) and direction with time.

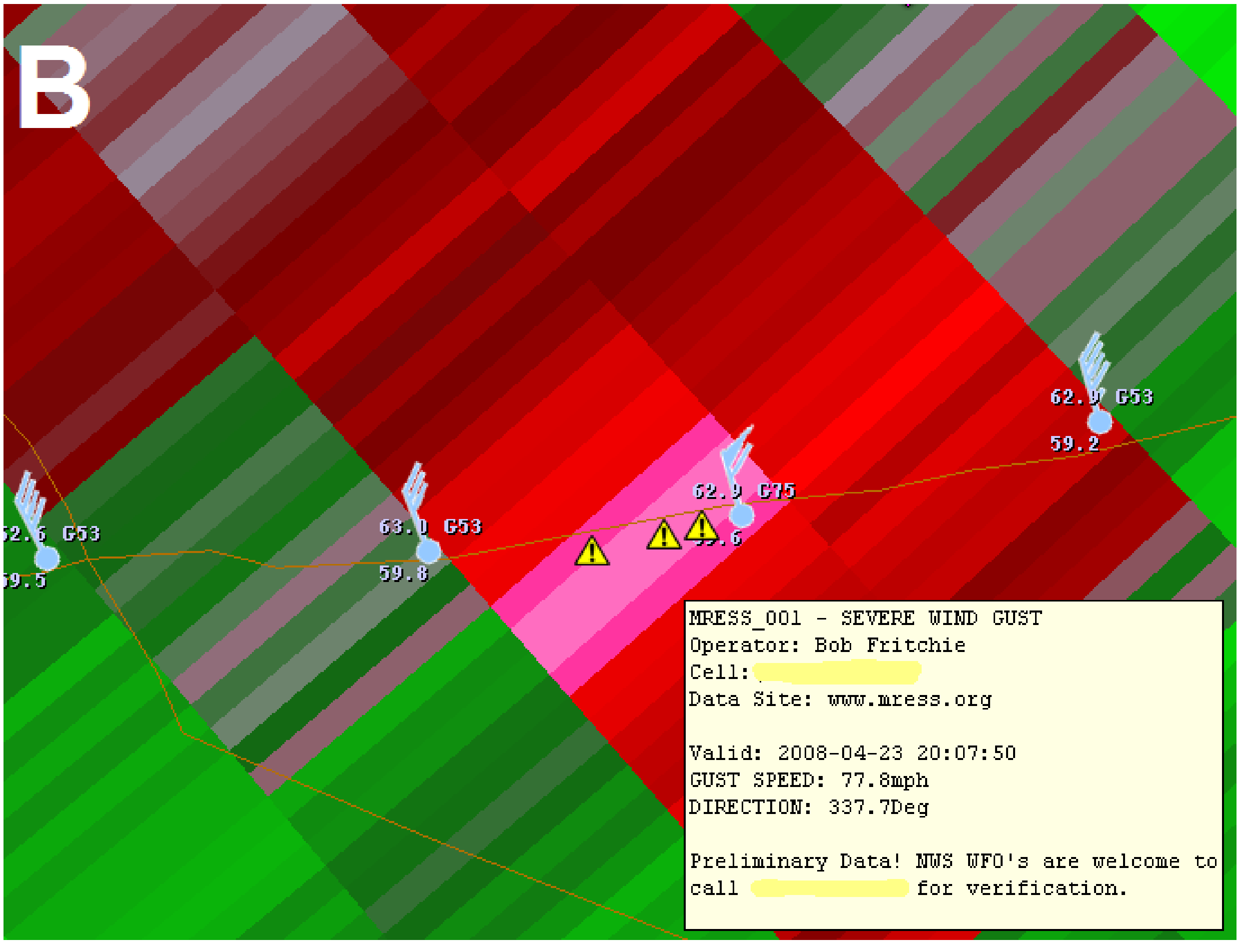

Figure 9b. Same as in Fig. 9a except for MRESS placefile within GRLevelX showing standard station as in Fig. 8a. Yellow exclamation triangle symbols denote severe winds forwarded to the SN.

Figure 10. Screen capture of a live chase cam in action near Hoxie, Kansas on 22 May 2008. This streaming video was monitored in real-time by the NWS Goodland, Kansas. Click here (http://www.nwas.org/ej/2009-EJ2/fig9video.wmv) to watch the video. Video by Matt Grantham.