Enriching the Modern Day Storm Spotter Through Technology & Education Enhancements

Joshua J. Jans[1] and Dr. Cecil Keen[2]
Spotter Network Inc., Wheaton, IL 60187[1] and Minnesota State University, Mankato, MN 56001[2]

1. INTRODUCTION

It has been said, "Storm spotters are, and always will be, an indispensable part of the severe local storm warning program" (NWS, 2009). Since the early 1940's, volunteer spotters have been observing and communicating ground truth information to public servants engaged in the protection of life and property (Doswell et al., 1999). A once small military and aviation based network of weather observers has grown substantially since 1965 with the inception of the National Weather Service (NWS) SKYWARN® Program and in 2006 with Spotter Network©. The present day spotter community includes members from all walks of life including emergency management, firefighters and rescuers, law enforcement, amateur radio operators, storm chasers, and concerned citizens (Figure 1). With advances in science and technology and thus data reporting, it is incumbent upon spotters to have some degree of common education and standards of reporting and tracking so that public safety personnel can rely upon the reports they are receiving.

Figure 1: While members of the storm spotter community have a diverse background of education and roles, they share a common bond in storm reporting to protect life and property.

The 2011 severe weather season was again a reminder of the increasing vulnerability faced by communities large and small throughout the United States. With fourteen separate $1 billion weather and climate disasters (Figure 2), the role of spotters and reports they submit are increasingly being used within multiple domains ranging from real time use by public safety personnel to post storm high dollar insurance claim verification (Figure 3). With seven out of the fourteen events being caused by severe thunderstorms, it becomes clear of the relevance the spotter community fulfills in national safety and for other stakeholders in the public and private domains.

Corresponding author address: Joshua Jans
Spotter Network, Inc.
2206 N. Main, Suite 166
Wheaton, IL 60187
E-mail: joshua@spotternetwork.org

Event	Date	Cost	Deaths
October Northeast Snow Storm**	October 29, 2011	$3+ billion	27
Tropical Storm Lee**	September 8, 2011	$1+ billion	13
Hurricane Irene	August 26-28, 2011	$7.2 billion	46
Missouri and Souris River Flooding	Spring-Summer 2011	$2 billion	5
Texas Drought & Wildfires	Spring-Summer 2011	$5.2 billion	2*
Mississippi River Flooding	Spring-Summer 2011	$5.0 billion	1*
Midwest, Southeast, Plains Severe Storms**	June 16-22, 2011	$1.25 billion	0
Midwest/Southeast Tornado Outbreak	May 21-27, 2011	$8 billion	177
Midwest, Southeast, Plains Severe Storms	April 19-21, 2011	$1.0 billion	0
2011 Super Outbreak	April 25-30, 2011	$9.0 billion	321
Midwest/Southeast Tornado Outbreak	April 14-16, 2011	$2.5 billion	38
Southeast/Midwest Severe Storms	April 8-11, 2011	$2.25 billion	0
Midwest/Southeast Severe Storms	April 3-5, 2011	$2.5 billion	9
Groundhog Day Blizzard	January 29-February 3, 2011	$3.9 billion	36

* These deaths were not included in the NCDC report
** This disaster was has not yet been included in the NCDC report

Figure 2: Table represents a preliminary breakdown of the fourteen different $1 Billion disasters that impacted the United States in 2011 along with reported fatalities (NCDC 2011). *Image courtesy of Jeff Masters at wunderground.com*

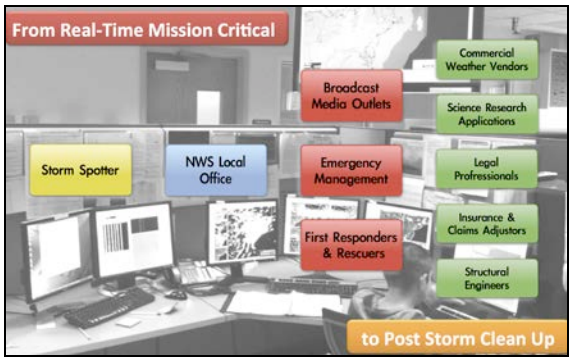

Figure 3: Image depicts the flow of spotter reports to stakeholders for real-time to post-storm evaluation.

2. STORM SPOTTER ROLE

The primary mission of a storm spotter is to provide real time ground intelligence in the form of storm reports directly to the NWS. The NWS warning process often begins with a forecaster receiving a spotter report(s) to confirm the observations being monitored at the various NWS Weather Forecast Offices (WFO). The spotter reports give confidence in issuing or not issuing, upgrading or downgrading, and giving credibility to the

wording for a call to action in a severe weather warning. Supported by a recent study on *Tornado Warning Communication and Emergency Manager Decision-Making* by League et al. 2011 showed that storm spotter reports were also a key source of verification data for Emergency Management decision-making processes.

The NWS SKYWARN® Program has an estimated 300,000 spotters whose primary function has been in the reporting of severe convective thunderstorm hazards including tornadoes, wall clouds, funnel clouds, hail, and flash flooding. At present, SKYWARN operates in a fragmented manner operating either through local WFO or through unregulated local, state, or regional groups and/or chapters that may or may not work directly with a local WFO. According to skywarn.org, there are over 200 independent groups with many more likely not listed (Figure 4). These SKYWARN groups and/or chapters often differ in their membership requirements in age, training, testing, amateur radio licensing, and professional associations. Storm spotters may also operate on an individual basis having no association with either a local WFO or independent group or chapter. With the NWS encouraging anyone with an interest in public service to join SKWARN, as a national organization with a formalized registration, training, and testing requirements, it is not.

Figure 4: The SKYWARN Program has at least 200 different chapters or groups listed as shown on skywarn.org.

2.1 Local Storm Reports

The *National Climate Data Center* (NCDC) is the custodian for all weather related data. Local Storm Reports (LSR) originating from various data collection sources, agencies and personnel (35 different categories in all) are stored by NCDC and published monthly in a report called Storm Data. Using Storm Data information for the period of January 1, 2007 to December 31, 2011, a total of 328,739 LSR's were recorded with 190,766 being thunderstorm related hazards. For these thunderstorm related LSR's, the top fifteen of NCDC's thirty-five categories of affiliations of persons submitting these LSR's are shown in Figure 5. These are, according to NCDC's terminology, mostly coming from Trained Spotters *(aka volunteer citizens)* (23%), followed by Law Enforcement (18%), The Public (17%), Emergency Management (13%), Amateur Radio Operators (5%), and towards the bottom of the listing Fire & Rescue (2%) and Storm Chasers (1%). The actual categorization of each source is not necessarily straightforward and needs to be better defined and likely expanded to include more modern day reporting sources. It is worth noting that the storm spotter community as a whole (as depicted in Figure 1) was responsible for approximately 62% of the thunderstorm related LSR's. This was calculated by summating six thunderstorm related event categories from the NCDC's forty-eight Storm Data Weather Event listing types. While thunderstorms were the main focus, the spotter community also reported on several different localized hazards including avalanches, dust storms, tropical storms, lake effect snows, and wildfires to name a few. In Figure 6, the top ten reported weather phenomena by the spotter community beyond thunderstorms were winter related weather events (73%) followed by flooding (16%), high wind events (8%), high surf (5%), and strong winds (3%).

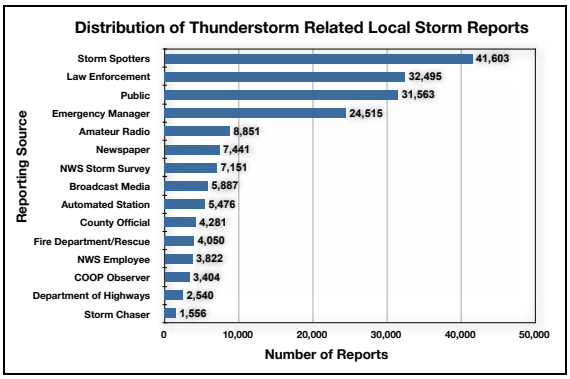

Figure 5: A frequency distribution of the sources of reports taken from 190,766 LSR's sent into the NWS between January 1, 2007 and December 31, 2011 as reported in Storm Data.

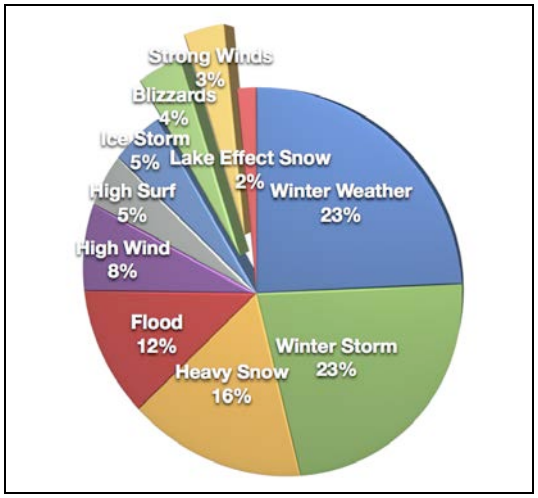

Figure 6: Depiction of the top ten other weather hazards reported in Storm Data submitted by the spotter community including trained spotters (aka volunteer citizen), law enforcement, emergency management, fire & rescue, and amateur radio operators.

While SKYWARN has been synonymous with thunderstorms, several WFO's have taken advantage of using spotters for other local weather hazards in their forecast area. For example, several WFO encourage

SKYWARN spotters to also participate in their Snow Spotter programs for reports on snow and ice accumulation, which coincides with the results shown in Figure 6. The extension to multi-hazard spotters is clearly advantageous for local WFO's, but comes again at the discretion of each of the 122 local WFO's. Any such training and reporting procedures for these spotters would be determinable at each local WFO.

2.2 Mobile Technology & Social Media

A paradigm shift is underway within the spotter community in response to the rapid adaption of web-enabled devices combined with the widespread availability of 3G cellular networks. Smart phones, tablets, and laptops have provided easy access to a plethora of weather display and tracking applications that augment an extensive menu of real time radar and data products on the fly whether one is at home, at the office, or even on the road (Figure 7).

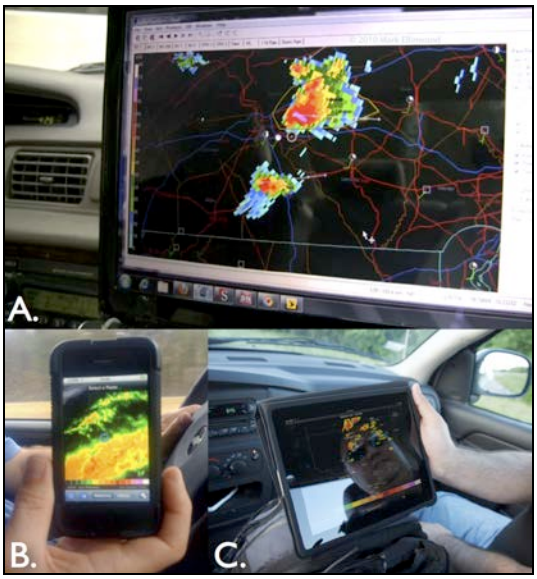

Figure 7: Technologies available to the modern day storm spotter include personal laptops (A.), smartphones (B.), and tablet devices (C.), which can embrace 3G cellular networks to provide easy access to weather data from nearly any location. *Images courtesy of (A.) Mark Ellinwood at ellinwoodweather.blogspot.com (B.) Richard Foreman at theweatherobserver.com, and (C.) Patrick Michael McLeod at flickr.com/people/misternaxal/*

Storm reporting methods have also proliferated with the infusion of Web 2.0 applications (e.g. Twitter, Facebook, Google Maps, etc.) to communicate in real time with geo-located storm reports, photos, videos, and tracking information. Presently, there are eight different methods accepted by SKYWARN to submit reports to the local WFO (Figure 8). Each method carries inherent advantages and disadvantages. There is no national standard as to which method should be used. It is up to each of the 122 local WFO, which is acceptable by them.

Figure 8: A depiction of spotter reporting methods: Local NWS Phone, Email, Web Form, eSpotter, Amateur Radio traffic, CoCoRaHS, NPOP, and Twitter. Each local WFO has a preferred method of reporting – a challenge when spotters travel or move from one WFO warning area to another.

Since 2010, the NWS has been experimenting with Twitter for data mining of significant storm reports. Information on this use can be found at *weather.gov/stormreports*. Twitter, a micro-blogging website, allows users to post geo-tagged messages of 140 characters (known as a Tweet). Any of the 383 million Twitter users around the globe can submit a report to *#wxreport* and can attach a picture or video through 3rd party applications. The WFO or any online user can use the Twitter Search API to run searches against the real-time index of recent Tweets and map out the results in a web mapping service like Google Maps (Figure 9). The NWS hopes to use Twitter to obtain weather information from this untapped army of amateur weather enthusiasts according Brice and Pieper 2010.

Interestingly, while Twitter has an impressive 108 million users in the U.S, a recent study indicated that only 28% of the users actually 'tweeted' during the three-month period that was studied (Semiocast 2012). Clearly, the vast majority of users are consumers of information rather than sharing it. This can also be positively read as another source of issuing warning information by weather agencies. However, anyone with a Twitter account can submit a report regardless if they are trained or untrained during severe and hazardous weather. In addition, data mining searches can yield unexpected or spam results. Finally, 'tweets' are not currently saved to any database and are deleted after a period of time, at Twitter's discretion (typically about 7 days), which could be problematic for verification purposes.

Facebook Pages are another social networking utility that NOAA-NWS and local WFO's have adopted recently (Figure 9). This web application allows users a two-way interaction with web links, discussions, surveys, comments, pictures, and videos. As a storm reporting tool, Facebook has been gaining traction, however, it is not a searchable resource and is limited in reach and visibility to the Facebook Page's "Fan" base.

These mobile technologies and Internet based tools have given the weather community new challenges. Fundamental to all is an adoption of a uniform reporting system and a means of identifying certified trained

spotters whose reports can be authenticated. In Spring 2011, SKYWARN officially recognized SN as part of its accepted methods to submit storm reports. It still remains up to each WFO whether they use SN transmitted reports or not.

Figure 9: On the left is an example of the experimental NWS Twitter Search Application in action pulling in tweets with *#wxreport* and associated weather hazards embedded within the message. On the right, an example Facebook Page from the NWS WFO in Fort Worth, TX. The NOAA-NWS has been utilizing this as a social media tool to supplement its efforts in public outreach.

3. SPOTTER NETWORK©

Since 2006, when SN was introduced by Pietrycha *et al. 2009* and later *Jans et. al.* 2010, membership has increased to 21,500 with 5,800 having passed the certified online training offered. SN is now a national community supplementing SKYWARN and has boosted its capabilities and outreach to a STTARS status offering a complete ***S***potter ***T***raining, ***T***racking and ***R***eporting ***S***ystem (Figure 10).

SN operates through a nationwide advisory committee of twenty-one individuals representing all parties interested in severe weather. The advisory committee functions with four foci:

- **NWS Operations** - Made up of six Warning Coordinator Meteorologists (WCM's) from AZ, KS, MT, MO, & OK
- **Emergency Operations** – Consisting of five representatives from Fire & Rescue, Emergency Management, and SKYWARN
- **Meteorology & Training** – Represented by three meteorologists from private, education, and research organizations.
- **Strom Chasers** – Consisting of four field-experienced chasers.

3.1 Spotter Network Training

Standardized training became a requirement in 2009 for all SN members in response to a growing concern over poor quality of storm reporting. The SN Training Center is an online Moodle-based program using open-source PHP web applications (Figure 11). The pedagogical style provides participants with a visually rich adult learning environment in which modules sequentially build a practical and applicable understanding to storm spotting and reporting.

Since the first Awareness Level Training Course became available, there have been nearly 15,000 attempts at completing the testing stage of the course. With 5,800 individuals successfully passing the course, it is apparent that the course is setting a respectable standard and attaining a common baseline of knowledge within SN. Participants who have passed the training course are given storm reporting privileges through SN.

Figure 10: Spotter Network's new vision as STTARS: embracing standardized training, national registry, reporting and tracking.

In summer of 2012, SN is planning to release several more training modules enhancing the Awareness Level Course to become an "All Weather Hazard" resource center. These modules will include winter storms, hurricanes, and wildfires. Users will have the option to receive specific training in weather hazards for their particular geographic location.

Future curriculum developments will expand from an Awareness Level to an Operations Level Training Course. This will focus upon providing a depth to weather phenomena and an understanding of technology used in weather forecasting, in-field mobile and stationary devices and in advanced reporting within the NWS system.

Figure 11: Depicts the SN online learning environment showing the modules for each section of training (Left) and an example of the visual appeal of the curriculum style used (Right).

3.2 Spotter Position Reporting

SN offers a unique position reporting feature that allows spotters and chasers to be tracked in real time. Position reports are updated through location aware devices with cellular, Wi-Fi, and Global Positioning System (GPS) networks utilizing a SN agent for Windows, APRS, GpsGate.com, RadarScope for iPhone/iPad, the WindowsMobile agent, a Blackberry agent, or an Adroid agent. Position reports can also be updated manually if GPS access is not available.

SN members can opt to provide contact information associated with their position icon including phone number, email, amateur radio call sign, radio frequency, website, and/or instant messaging handle. All users are required to show their identification of first and last name. SN spotter contact information is always made available to NWS employees and other verified Emergency Management personnel serving in the best interest of public safety (Figure 12). SN users also have the option to make their contact information available to the public if they so choose.

In 2011, over 5,000 SN members utilized this position reporting feature. The top map in Figure 13 shows the initial log in location of users who turned on the geo-tracking option for the first time in 2011. This was likely to be at or near the vicinity of users place of residence in most cases. The bottom map in Figure 13 shows the cumulative tracking of those 5,000+ users on a nationwide scale in 2011. These users were responsible for logging over 18 million position reports providing an impressive spatial coverage of the U.S. Once again, all position reports are stored and identifiable.

Figure 12: An example of the SN in action on July 30, 2011 north of Minneapolis, MN. On the top image, the red dots indicate active SN members during a severe thunderstorm event. By clicking on any of the red dots, the spotter name (John Doe) and available contact information are made visible as seen in the bottom image.

One of the lesser-known features of SN's capability is the capacity to create sub-groups of users. For example, as shown in Figure 14, the Twin Cities WFO has a member network of 215 spotters. They are, via a custom data feed from SN, able to be exclusively monitored by the Twin Cities NWS forecasters and SKYWARN coordinator during times of severe weather. This provides a local management capability for specific users and/or regions. For emergency managers, this makes a powerful tool for tracking and monitoring of field personnel and volunteers.

Figure 13: The top map shows the very first position report made by each registered SN user in 2011. This was likely at or near their residential location. The bottom map displays the accumulation of position reports throughout 2011 by 5,000+ SN users during 2011. Imagine adding to this the 300,000 members of the SKYWARN community if they utilized the same technology platform.

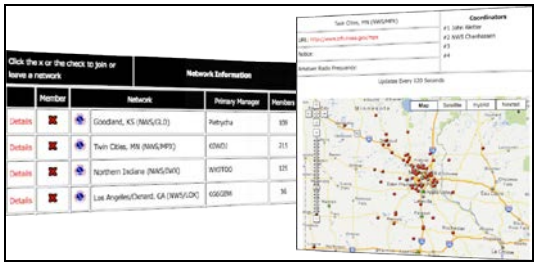

Figure 14: Image depict a sample listing of SN Member Network or sub group feature (Left) that allows local WFO's, SKYWARN chapters, Emergency Management Agencies (EMA) and other related groups to create community like groups with a private feed for monitoring their members. Upon clicking "Details", a Network Details webpage (Right) is loaded with relevant details about the group and activity dots in red and green showing the geographic location of active (Green Dots) and inactive (Red Dots) members.

3.3 Quality Reporting

SN utilizes online storm reporting forms for its users. The forms follow a NWS reporting guideline used to standardize terminology and aid in correctly identifying hazards and location. SN is continually attempting to improve upon the quality of reports and since each report is identifiable it becomes easier to sift good users from poor. Every report is reviewed and graded by members of the SN Advisory Committee. Should there be consistently poor grades coming from any user, that person is first warned, then after a second time they are required to repeat training and if after two such warnings, they are removed from SN. If a member submits a bogus report, that member is permanently removed from SN. The intent of these accountability rules is to provide a consistent quality to the reports being submitted by users.

3.4 The SN Weather Spotter Safety Program

SN recognizes storm spotters as being both stationary and mobile in practice. As such, their personal safety is of the utmost concern. SN has therefore initiated the *10 Golden Spotter Safety Rules* (Figure 15). These are built into the SN training modules and are part of the requirements of passing the course. Each rule is applicable to all aspects of storm spotting and participants are encouraged to coin the phrase ACES as a mantra for behavior (Figure 16).

Figure 15 The 10 Golden Spotter Safety Rules are aimed at ensuring that the safety of the spotter is the number one priority above all things.

3.5. Towards a Final Solution

What is required for a comprehensive solution is becoming clear to many weather personnel. That SN provides a proven template, which could enhance and enrich the current SKYWARN Spotter Program. Figure 17 is a summary of the features by which SN operates. As a single entity, SN oversees training, data management and quality assurance, visual depiction to both spotter and end-user, and the layering of needs by selected agencies/users whose overall quest is public safety. The interlacing of major technologies and protocol requirements are seamlessly accomplished with SN embracing an open data concept. Everyone participating plays a linking role in the overall vision of weather events. What is missing perhaps is a bipartisan desire on the part of competing agencies.

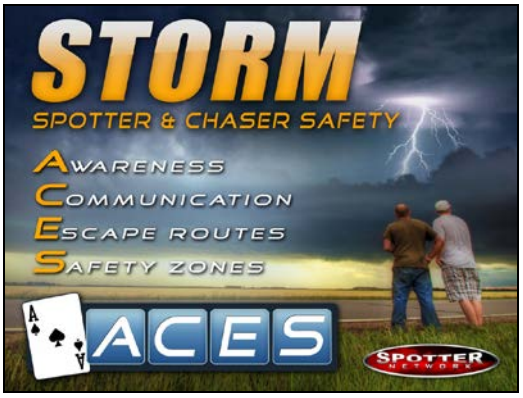

Figure 16: ACES Spotter & Chaser Safety is part of the SN training program that places a heavy emphasis personal safety.

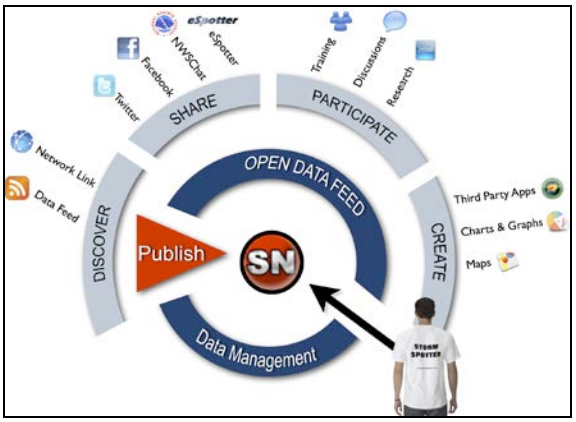

Figure 17: An overview of Spotter Network depicting it as a complete management system with an open-data philosophy for easy accessibility for both volunteers and pubic safety personnel.

4. CONCLUSION

Technological advances have enabled storm spotters to operate in a new paradigm of action. Bureaucratic vacillations often thwart large government agencies in reacting quickly to such technological enhancements. This has been true of the SKYWARN Program. Even with a defined mission, it operates as separate entities and its participants are unregulated with little connection between their field operations. SN is relatively new to the market and is a complimentary service for the NWS and Emergency Management Agencies. It exists as an online organization and governed by representatives from all branches of weather operations. Participants in SN are required to undertake an Awareness Level training so that all users are familiar with terminology and processes that can be described and reported in a standardized

manner. Each registered user can be tracked and corresponded with while in the field and their reports are identifiable and saved for post-incident analysis and re-evaluation. The advantages of such an online system are extendable to all levels of emergency management and public safety. It is timely to consider a merging of missions between SKYWARN and SN with the recognition that as an independent agency (SN) can significantly aid NWS personnel in their quest towards public safety. With some spotters already recognizing and reporting on all types of weather hazards, it may be a timely opportunity to extend the convective weather umbrella to 'All Weather' spotting. The infrastructure is available, it just takes an innovative action by proactive thinkers to create a condensation nuclei. With the NWS's new venture advertised as being a *Weather Ready Nation*, it is incumbent upon all interested parties to merge resources and weather the storms together.

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