The Digital Revolution of Storm Spotting
Modernizations of Training, Tracking, and Reporting

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A Non-Profit Corporation

1. INTRODUCTION

The 2011 tornado season will be long remembered as one of the deadliest, most devastating, and costliest seasons recorded in modern day U.S. history. Raleigh & Jacksonville, NC *(Two EF-3 - April 16, 2011)*, Tuscaloosa, AL *(EF-4 - April 27, 2011*), Joplin, MO *(EF-5 – May 22, 2011)*, Minneapolis, MN (EF-1 – May 22, 2011), and Springfield, MA (EF-3 – June 1, 2011) were just a few of the communities marred with deadly tornadoes. They caused significant damage over densely populated urban areas and contributed to the 537 fatalities reported so far this season (Figure 1 & 2). Behind the scenes of these unfolding weather disasters were countless volunteer storm spotters who played a pivotal role in the warning process for the National Weather Service (NWS), the Emergency Management Community, and Broadcast Meteorologists. They provide ground truth reports, confirmations, and often a forewarning of the magnitude and scope of a weather disaster. They also inadvertently provide pinpointed areas of interest for the NWS when a damage survey is necessary.

Figure 1: A screen capture of the Tuscaloosa, AL tornado later rated an EF-4 from April 27, 2011 was one of many 'Downtown' tornadoes to impact a densely populated urban area in 2011. *Image courtesy of FOX6 WBRC-TV*

1.1 Technology Infused Storm Spotting

Storm spotters have been around for more than half a century. Recent wide spread adaptation of relatively inexpensive technological innovations in mobile Internet access, web-based reporting systems, and live streaming video are rapidly changing the landscape within the weather communities. A newcomer to the weather community, Spotter Network, has been instrumental in the utilization of these resources. Recent activities by both SKYWARN and Spotter Network have pushed the agenda to implement uniform training standards and reporting structures in the spotter system (Figure 3). The need to create a more organized and standardized flow of information to relevant and targeted stakeholders has become necessary. Additionally, digital enhancements in storm reporting that include real-time location tracking and live streaming video are now being interfaced with a number of different web-based weather graphics and mapping programs. This provides another dimension to the concept of disaster management, allowing for the ability to create efficient coordination, collaboration, and sharing of critical time sensitive information for public safety organizations. The demand for in-situ spotter intelligence is growing beyond just tornadic severe thunderstorms, but now encompasses interest in all severe and hazardous weather events - flooding, tropical storms and hurricanes, wildfires, and winter storms. By utilizing these persons and technologies for all types of disasters significantly enhances the efficiency among all of the public safety agencies. This will imply and likely require extending the training options for observers who aspire to be ALL-HAZARD Spotters.

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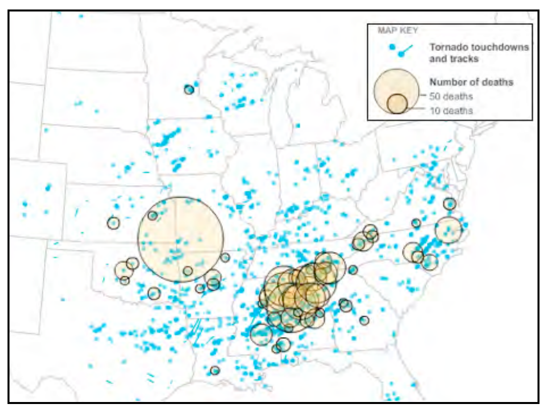


Figure 2: A map created by the *New York Times* depicts the 2011 preliminary tornado reports and tracks up to May 23, 2011 with the number of deaths represented by scaled tanned circles.

2. STORM SPOTTER COMMUNITY

The origins and history of storm spotters is well covered in "*Storm Spotting and Public Awareness since the First Tornado forecasts of 1948"* by Doswell et al. The deadly April 11, 1965 Palm Sunday outbreak of tornadoes resulted in the founding of SKYWARN as part of the Natural Disaster Warning system (NADWARD).

SKYWARN has since become the primary national spotter program with an estimated 300,000 storm spotters throughout the U.S. according to a recent annual tally from all 122 local NWS Weather Forecast Offices (WFO). An exact spotter count cannot be easily determined as there is no centralized registration system.

Since its conception, SKYWARN was intended to promote a cooperative effort between the NWS and local communities. The emphasis of the effort is focused on the storm spotter, an individual who takes a position near their community and reports wind gusts, hail size, rainfall, and cloud formations that could signal a developing tornado. While SKYWARN is recognized as a national organization, it receives minimal federal funding and operates at its best potential under the circumstances. To compensate this shortfall, SKYWARN de-centralizes and effectively operates in individual chapters, or groups, or simply on an individual basis. This presents a number of challenges to streamlining and standardizing the reporting and training of spotters across the country.

Figure 3: SKYWARN represents the largest spotter program in the U.S. and has recently began working with Spotter Network in an effort to bring about modernization in training, tracking, and reporting.

2.1 Spotter Network

Since the establishment of Spotter Network in 2006, it has been fervent in bringing storm spotters, storm chasers, coordinators, and public servants together in a seamless network of information during periods of severe convective and more recently winter weather. This grassroots network was conceived by Tyler Alllison and is now guided by an advisory committee with members from the NWS, emergency responders, research & training meteorologists, and storm chasers. All of the participants have a common objective toward enhancing the flow of real-time storm information without taxing human resources in the field and the recipient stakeholders involved in public safety (Pietrycha et al., 2009). The Spotter Network system provides accurate real-time-position tracking data through a combination of locally installed software for position and status reporting and web based processing and mapping that can easily be integrated into a variety of readily available software/technologies including NWSChat & eSpotter, Google Maps©, GRLevelX, and RadarScope to name a few (Figure 4 & 5). Spotter Network has quickly expanded in popularity since it's debut in 2006 growing to over 17,000 participants as of this writing.

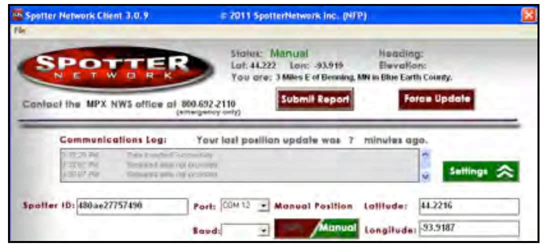


Figure 4: Image depicts the Spotter Network client for Windows that provides GPS tracking, local NWS office phone, communications log, Spotter ID, and Submit Report option.

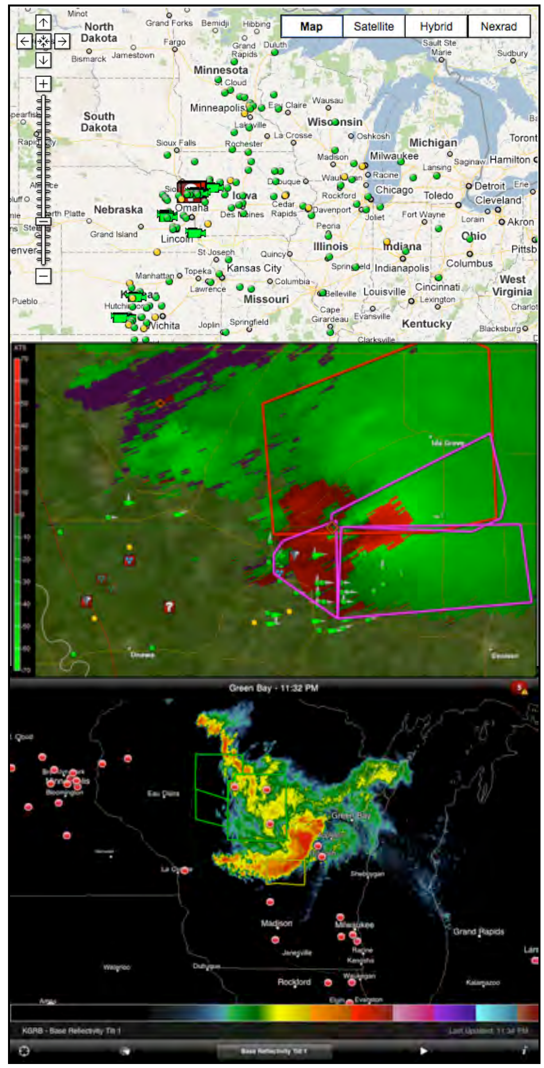


Figure 5: Spotter Network integrates effortlessly into many mapping and weather program by providing various data feed formats (XML, TXT, KML, etc.) available for use in third party products such as Google Maps© (TOP), GRLevel3 & GR2Analyst (MIDDLE), and Radar Scope for iPhone and iPad (BOTTOM), which can display live tracking position icons of mobile or stationary storm spotters along with personal information if made available by the individual.

2.2 In-situ Live Streaming Video

With the expansion and reliability of 3G mobile broadband networks and the advances in video compression technology, a growing number of dedicated dash-cams are being installed by storm chasers to provide live streaming video (also known as live chase cams - LCC) during their field excursions (Pietrycha et al., 2009). Since its introduction in 2007 by SevereStudios.com, a handful of companies have come onto the market to offer armchair experiences of live geo-referenced storm chase observations and even audio commentary over the Internet (Figure 6).

- ChaserTV – 150+ Streamers
- SevereStudios.com – 45 Streamers
- TornadoesVideos.net/ iMap Tracker – 14 Streamers
- StormChaseILve.com – Unknown

Figure 6: A growing number of storm chasers and mobile storm spotters are outfitting their vehicles with dash-cams connected to onboard laptops to provide live streaming video footage of their convective encounters via the Internet. *Image courtesy of Staton Breidenthal of nwaonline.com (*TOP) These streams are made available through dedicated websites that provides a live view of what the streamer is seeing along with GPS location data mapping out their current location. *Image courtesy of Andy Gabrielson & SevereStudios.com. (*MIDDLE) ChaserTV has become quite popular in 2010 with the introduction of the 'Video Wall' of all of their active streamers currently online. *Image courtesy of ChaserTV.com* (BOTTOM)

These live streams have the capability to be another real-time ground truth observation to compliment or negate storm reports. The streamer population, however, will likely remain a limited resource in the foreseeable future in comparison to the overall population of storm spotters and chasers due to the cost of outlay and disruptions and/or overloading of cell phone towers and antennae. Regardless, live video streams have already proven to be a distinct advantage during a severe weather event.

2.3 Spotter Categorization

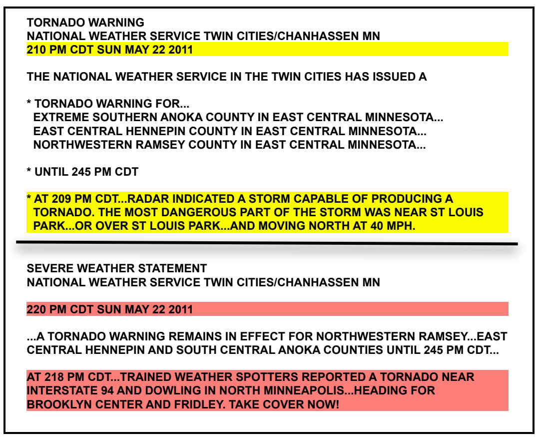
The spotter population is currently made up of a broad spectrum of individuals ranging from law enforcement and fire department personnel, dispatchers, emergency management, amateur radio operators, private citizens passionate about severe weather and public safety, and even storm chasers who will often times play a hybrid role to make critical reports (Figure 7).

Storm spotters are generally categorized as 'stationary' or 'mobile'. A stationary spotter will report severe weather from their registered locale at home or at work. A mobile spotter, on the other hand, will observe storms from their vehicle and attempt to move with the storm to maintain visual view and report any severe weather that meets the minimum severe weather reporting criteria for their current NWS County Warning Area. Storm chasers differ from mobile storm spotters in the fact that chasers will travel hundreds of miles and across state(s) lines to see severe weather and often have different motivations including scientific field programs, storm photography, self-education, commercial videography and photography and even storm chasing tours (Edwards & Vasquez, 2000). Regardless of the spotter type, the most important task a spotter will do is to make a storm report. In most cases, the report will become the official record of the NWS office, which will be logged as a Local Storm Report and if applicable actionable decisions are made.

Figure 7: The modern day Storm Spotter Community is made up of wide variety of backgrounds ranging from emergency response personnel to concerned citizens.

3. STORM REPORTS & TRAINING

Local Storm Reports (LSR), are products issued by local NWS offices to inform users of observations of severe and/or significant weather-related events. During severe thunderstorms, this may include funnel clouds, tornadoes, hail, thunderstorm wind gusts, rainfall amounts, and any notable thunderstorm related damage. NWS forecasters use this information as ground truth data and correlate it with Doppler radar observations. The combination of a LSR and a Doppler radar signature gives the radar forecaster greater confidence in the warnings and follow-up statements that are issued (Figure 8). Certain LSR such as tornadoes, severe hail ≥ 1.00 (2.54 cm) in diameter, and thunderstorm wind gusts and/or damage reports are also received and published online by the Storm Prediction Center (SPC) as preliminary data (Figure 9). Eventually all of these LSR are published in final form in the National Climatic Data Center (NCDC) STORM DATA publication.


TORNADO WARNING
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN
210 PM CDT SUN MAY 22 2011

THE NATIONAL WEATHER SERVICE IN THE TWIN CITIES HAS ISSUED A

* TORNADO WARNING FOR...
EXTREME SOUTHERN ANOKA COUNTY IN EAST CENTRAL MINNESOTA...
EAST CENTRAL HENNEPIN COUNTY IN EAST CENTRAL MINNESOTA...
NORTHWESTERN RAMSEY COUNTY IN EAST CENTRAL MINNESOTA...

* UNTIL 245 PM CDT

* AT 209 PM CDT...RADAR INDICATED A STORM CAPABLE OF PRODUCING A TORNADO. THE MOST DANGEROUS PART OF THE STORM WAS NEAR ST LOUIS PARK...OR OVER ST LOUIS PARK...AND MOVING NORTH AT 40 MPH.

SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN

220 PM CDT SUN MAY 22 2011

...A TORNADO WARNING REMAINS IN EFFECT FOR NORTHWESTERN RAMSEY...EAST CENTRAL HENNEPIN AND SOUTH CENTRAL ANOKA COUNTIES UNTIL 245 PM CDT...

AT 218 PM CDT...TRAINED WEATHER SPOTTERS REPORTED A TORNADO NEAR INTERSTATE 94 AND DOWLING IN NORTH MINNEAPOLIS...HEADING FOR BROOKLYN CENTER AND FRIDLEY. TAKE COVER NOW!

Figure 8: On May 22, 2011, a Tornado Warning was issued at 2:10 PM CDT by the Twin Cities NWS office based radar information. (YELLOW) Within a few minutes, a storm spotter report provided confirmation of a tornado. A follow up statement was issued at 2:20 PM with enhanced location information and call to action to "Take Cover Now!" (RED)

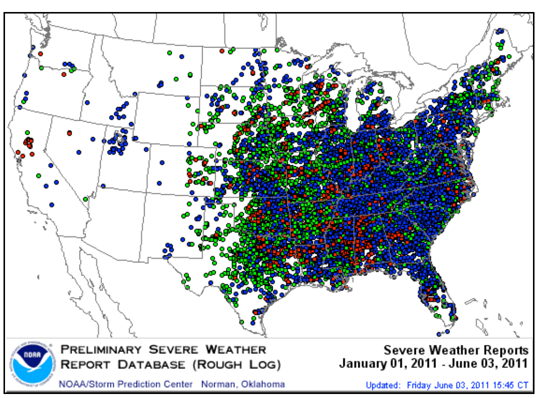


Figure 9: A map produced by SPC presents the 2011 accumulated LSR of tornadoes (RED), severe hail (GREEN), and damaging thunderstorm wind (BLUE) reports from January 1, 2011 to June 3, 2011.

Between January 1, 2005 and June 1, 2011, local NWS offices transmitted over 240,000 LSR[1] related to tornadoes, hail, and thunderstorm wind gusts and wind damage. An informal review of this rough log revealed that the Spotter Community was responsible for at least 60% of these reports (Figure 10). This percentage is likely higher since over 36,000 reports were missing a 'Source' identifier. A more detailed breakdown of these LSR suggests that Spotter Volunteers (or citizens) had the highest level of reporting with over 53,000 reports within the community. This was followed by Law Enforcement (~35,000), Emergency Managers (~23,000), Amateur Radio (~12,000), NWS Personnel (~4,700), County Officials (~4,300), Fire Departments (~3,800), and Storm Chasers (~1,500) (Figure 11).

In addition, LSR are also gaining wider utilization for real-time operational decisions and for post-storm evaluation by emergency managers, first responders, news media outlets, commercial weather vendors, insurance companies, claim adjustors, attorneys, research scientists, structural engineers and others. However, as pointed out by Changnon 1999, there can be significant drawbacks in using these LSR for certain research and application purposes. While the NWS makes every effort to ensure the accuracy of the information, the potential for errors does exist. It appears that there is a lack of consistency in formatting source identifier and associated remarks in addition to the hurry of the moment errors, which often results in magnitude, time, location and sequencing information being erroneous on part of the spotter or local NWS office. Perhaps a more rigorous reporting structure and spotter training would improve the quality of this valuable resource.

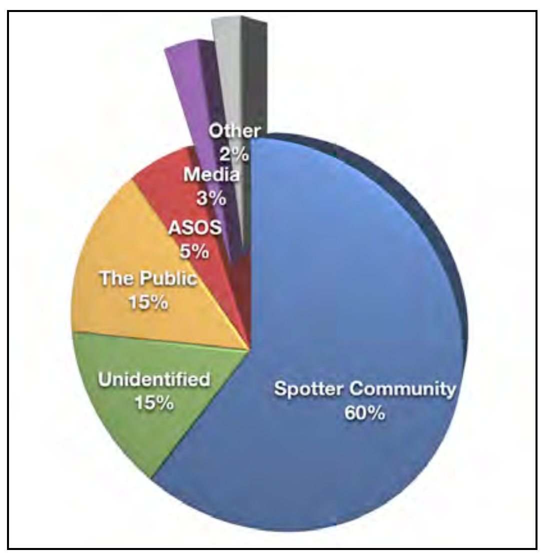


Figure 10: This pie chart represents a snap shot view of the source from which over 240,000 tornadoes, hail, and thunderstorm wind gust, and wind damage LSR were derived between January 1, 2005 to June 1, 2011.

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[1] LSR data was acquired through a private weather company database that received all hail, wind, and tornado related LSR as they were disseminated by each of the local NWS offices.

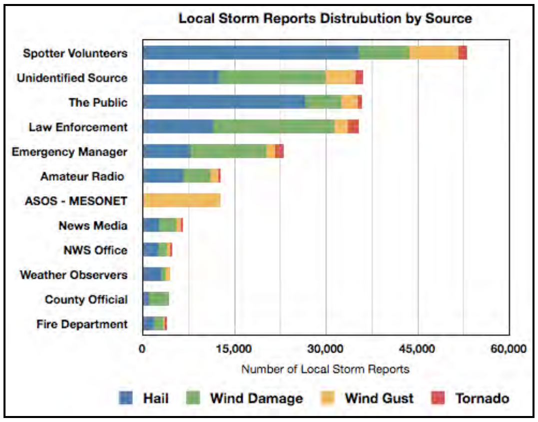


Figure 11: This bar graph shows the frequency of LSR made by the different sources broken down by report type including hail (BLUE), wind damage (GREEN), wind gust (ORANGE), and tornadoes (RED) between January 1, 2005 and June 1, 2010.

3.1 Questioning Quality Storm Reporting

Since 2008, the rapid growth of SN brought to the forefront a reoccurring issue in poor quality storm reporting. SN therefore implemented a dual solution of (1) specific online training and (2) a post storm-report quality control process for every report submitted. Realizing that this field report was the beginning of a series of subsequent safety decisions, it seemed imperative to train spotters and grade reports to ensure a high quality in reporting their observations. Furthermore, recognizing that NWS offices do not all use the same severe weather criteria, SN introduced standardization for minimum reporting thresholds. They were selected to span the widest range of recipient needs. SN spotters are tasked to report the following.

- All Tornadoes, Funnel Clouds, Wall Clouds
- All Hail Reports
- Only Wind Speeds and/or Gusts Greater than 50 MPH
- All Hydro Related Events (Flooding, Heavy Rainfall)
- All Significant Damage Generated from a Thunderstorm
- All Winter Weather Reports (Snowfall, Icing, etc.)
- All Tropical Storm and Hurricane Reports

3.2 Limited Training Availability

Up until 2008, the only spotter trainings available were through annual SKYWARN classes typically administered by a Warning Coordination Meteorologist from local NWS offices. These classes are PowerPoint presentations and last about two hours. They usually cover the topics listed below.

* *Basics of thunderstorm development*
* *Fundamentals of storm structure*
* *Identifying potential severe weather features*
* *Information to report*
* *How to report information*
* *Basic severe weather safety*

A recently developed online three-tiered weather-training program originally developed for first responders entitled "*Disaster Weather for Responders*" as outlined in Jans & Keen 2007 was used and retooled to fit SN training needs. The first *basic Awareness Level* Spotter Network course was developed as a background introduction to weather safety with the primary emphasis on thunderstorms and associated hazards. With a visually rich approach and simple science explanations, the focus was toward educating the spotter-in-the-field in weather awareness and implications with significant depth of content (Figure 12).

Figure 12: Image represents a snippet from the Flash Flood section of the Awareness Level SN online training exemplifying the visually rich nature of the course.

This Awareness Level course (Figure 13) is a requirement for all SN members who want to use SN to submit a report. This was implemented in 2009. Out of the 12,000 attempts at completing this course, nearly

5,000 observers have been certified as SN members. This combination of the online training, the check on the quality of each submitted report, and a stringent policy against false and/or bogus reports has aided greatly in improving reporting on SN.

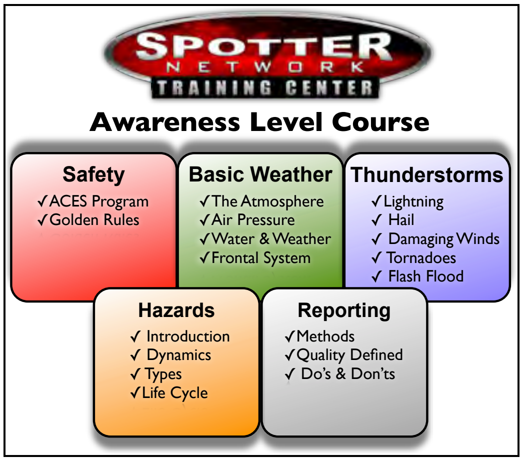


Figure 13: The online based Awareness Level SN training course is divided into five sections covering safety, basic weather, thunderstorms, hazards, and reporting.

3.3 SKYWARN Modernization Efforts

In 2009, the NWS undertook the task to modernize the SKYWARN Program. It was to occur in two phases under the NWS leadership team of John Simensky Tanja Fransen, and Chris Maier. The first phase was internally undertaken with the following objectives:

Phase 1

- Combine the Basic and Advanced Spotter Guidebooks into a single training guide and incorporate more recent scientific research and radar interpretation in the content (Figure 14). (Completed)

- Strategize on best practices and available resources to build a national online spotter registration system. (In planning – no final decision at this time)

- Planning the overhaul of the current NWS SKYWARN website. (In progress – partial completion)

In the second phase, the NWS invited external members to participate in the training aspects of spotters. Here members of SN joined forces to create and enhance the SKYWARN Online Spotter Training modules. To ensure funding for this project, it was submitted as part of the National Strategic Training & Education Plan (NSTEP) by the Training Branch at the NWS Headquarters and given to the Cooperative Program for Operational Meteorology, Education and Training (COMET) under the University Corporation for Atmospheric Research umbrella.

The online training development team consisted of over 20 individuals between the NWS, SN, and COMET who worked to create course objectives and outlines along with planning for a national database and SKYWARN website integration. Team topics included:

- *Overview & History*
- *Procedure*
- *Safety*
- *Basic Weather*
- *Convective Thunderstorms*
- *Winter Weather*
- *Flooding*
- *Hurricanes*
- *Marine*
- *Further Topics (future)*
- *Database & Website Design*

The initial funding, however, only provided support for the completion and online hosting of two modules. These were the '*Role of the SKYWARN Spotter*' and '*Convective Basics'*. These equated to a two-hour online course (Figure 15).

Figure 14: The new SKYWARN 'Weather Spotter's Field Guide' is scheduled to be released in late summer 2011 featuring 68 pages with updated thunderstorm research and radar interpretation for spotters.

Figure 15: SKYWARN released their first two online courses produced by the COMET Program released in April 2011 including '*Role of the SKYWARN Spotter*' and '*Convective Basics'*.

3.4 Reporting Methods

Presently, a SKYWARN spotter has up to nine different reporting methods to submit different types of thunderstorm related reports. There are advantages and limitations for each. Adding to possible confusion, each NWS office can have their own preferred method of receiving reports and even reporting criterions. The below list the methods currently available.

Telephone

- Local NWS Forecast Office
- National Public Observation Program

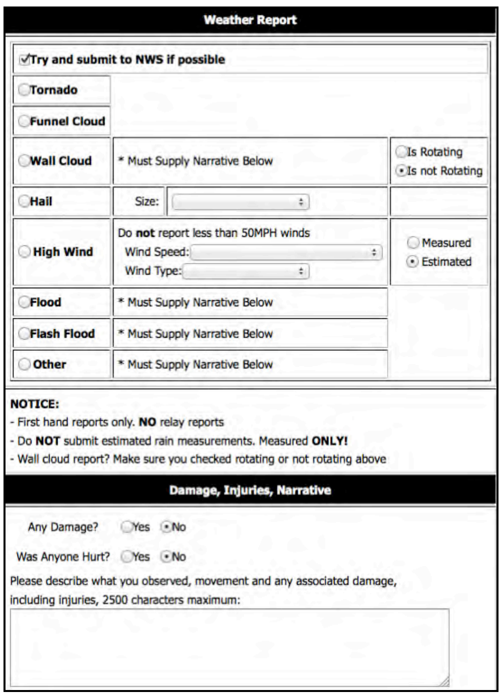
Internet

- Spotter Network
- eSpotter

- Twitter
- Local WFO Web-based Form
- Local WFO E-Mail
- Community Collaborative Rain, Hail and Snow (CoCoRaHS)

Amateur Radio

In an attempt to standardize the reporting system, SN created an online solution that utilizes an easy to use web form, which is sent to SN, NWSChat, eSpotter, and Twitter within five seconds with a single click (Figure 16). Furthermore, SN trained spotters are strongly encouraged to contact the local NWS office directly via phone for all life threatening events. The web-form automatically provides the spotter with the local NWS office phone number based on their Internet Protocol address (IP) or geolocation map data. In addition, these reports are stored in a database that can be employed in quality control, review, spotter activeness, and training improvements to name a few.


Weather Report
Try and submit to NWS if possible
Tornado
Funnel Cloud
Wall Cloud — * Must Supply Narrative Below — Is Rotating / Is not Rotating
Hail — Size:
High Wind — Do **not** report less than 50MPH winds — Wind Speed: — Wind Type: — Measured / Estimated
Flood — * Must Supply Narrative Below
Flash Flood — * Must Supply Narrative Below
Other — * Must Supply Narrative Below

NOTICE:
- First hand reports only. **NO** relay reports
- Do **NOT** submit estimated rain measurements. Measured **ONLY!**
- Wall cloud report? Make sure you checked rotating or not rotating above

Damage, Injuries, Narrative
Any Damage? Yes No
Was Anyone Hurt? Yes No
Please describe what you observed, movement and any associated damage, including injuries, 2500 characters maximum:

Figure 16: The SN web form includes spotter identification, IP or geolocaiton information, and the report type (as shown above), along with any narrative the spotter believes is significant.

3.5 Spotter Safety

One of the more important topics covered during the modernization collaboration meetings was Spotter Safety. Both SKYWARN and the SN agreed to emphasize the importance that "The Spotter's Personal Safety is the Primary Objective of Every Spotter." The intent of this is to ensure that each spotter clearly understands that the information they provide is critical for public safety and that they are responsible for providing accurate information. The spotter must not perform any act(s) that would jeopardize his/her own personal safety or that of any other person. This message is the core of the new ACES Safety Program designed to keep every spotter safe in any situation they might find themselves in (Figure 17).

Figure 17: The ACES Spotter Safety Program is designed to keep spotters safe in any situation. **Awareness** – The spotter should maintain situational awareness at all times. **Communication** - The spotter should maintain communication through cell phone, radio, or other means at all times. **Escape Routes** - The spotter should maintain escape routes at all times. **Safety Zones** - A safety zone is a place in which you will be safe from the oncoming severe weather event.

The ACES concept was adapted from the National Wildfire Coordinating Group LCES *(**L**ookouts, **C**ommunications, **E**scape **R**outes, and **S**afety Zones)* under the guidance of Safety sub team lead Lt. Randy Denzer and fellow collaborators from SN, and COMET.

4. A CALL TO ACTION

The last few years have brought forth a multitude of changes to the Storm Spotter Community in technologies, new training materials, and reporting options with more changes on the way. Several key components are readily available to provide a paradigm shift to transform the current fragmented spotter system into a cohesive interoperable nationwide network of ground intelligence that greatly enhances the flow of information to relevant and targeted stakeholders.

To foster these changes, the following opportunities should be considered for promoting a connected and qualified network of spotters.

4.1 Spotters to Fall Under Emergency Management

Storm spotters are recognized as '*Operations'* resources who gather and report information under the National Incident Command System (NIMS). NIMS is a comprehensive, national approach to incident management that is applicable at all jurisdictional levels and across functional disciplines (FEMA 2011). NIMS training is provided by the Federal Emergency Management Agency (FEMA). Under current budgetary constraints and the limitation of staffing of many local NWS offices, the timing may be opportune to move the SKYWARN Program from the Department of Commence to the Department of Homeland Security (DHS). DHS is better equipped and trained to manage the logistics and operations of an organization like SKYWARN. Similar citizen volunteers programs such as Citizen Corps and Community Emergency Response Team (CERT) have demonstrated significant success under the DHS – FEMA umbrella and get funded for their mission.

4.2 National Training & Certification

The majority of SKYWARN training is undertaken by the NWS through classroom presentations. Upon completion, the spotter is considered to be a 'Certified Storm Spotter'. There exist no standards in competency with student registration, national spotter ID assignment, testing of objectives or specific increment for retraining. Furthermore, training conducted by one local NWS office is not easily verifiable by another. This is especially so for spotters who report outside or move away from their resident NWS warning area.

The online SKYWARN training provided by COMET does provide a step in the right direction with standardization of at least the two-hour classroom course along with a test of knowledge. However, participant details of completion of this course are kept by COMET. For SKYWARN to function as a national organization, it should provide a national framework in training, certification, and registration. Perhaps SKYWARN could consider a merger or partnership with SN to implement these considerations.

4.3 Going ALL-HAZARD

With the escalation of disasters of all kinds in recent years, this may be an opportunity to extend storm spotter weather reporting to ALL-HAZARD reporting. The expansion of the current Spotter Community from weather only to ALL-HAZARD preparedness, training, mitigation, and recovery would be a dynamic concept towards public safety and outreach. Spotters could conceivably play a much larger and more active role in their communities with the infusion of a CERT team-like structure.

5. CONCLUSION

With the technology now available, there is the opportunity of having a nationally connected pipeline of certified trained volunteers who would be the eyes and legs for all-disaster response. This is an encouragement for a conversation towards these ends.

6. ACKNOWLEMENTS

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