1.1 OVERVIEW OF THE STORM PREDICTION CENTER

Roger Edwards[1], Gregory W. Carbin and Stephen F. Corfidi
Storm Prediction Center, Norman, OK

1. INTRODUCTION

The Storm Prediction Center (SPC) is a national forecasting center and unit of NOAA's National Weather Service (NWS) located in Norman, OK. The SPC predicts conditions favorable for severe and nonsevere thunderstorms, as well as for wildfires, across the continental United States (CONUS). The SPC is one of nine national centers comprising the National Centers for Environmental Prediction (NCEP) distributed around the CONUS, the others being the Aviation Weather Center (AWC), Climate Prediction Center, Environmental Modeling Center, Weather Prediction Center (WPC), NCEP Central Operations, National Hurricane Center, Ocean Prediction Center, and Space Weather Prediction Center. An organizational tree showing SPC's place in the National Weather Service (NWS), along with a map of NCEP, appears in Fig. 1. As with most of the other NCEP centers, SPC offers specialized guidance to a diverse audience that includes the general public, media, emergency managers, military, civilian governments at federal, state and local levels, and NWS local forecast offices. A history of the development of SPC appears in section 2.

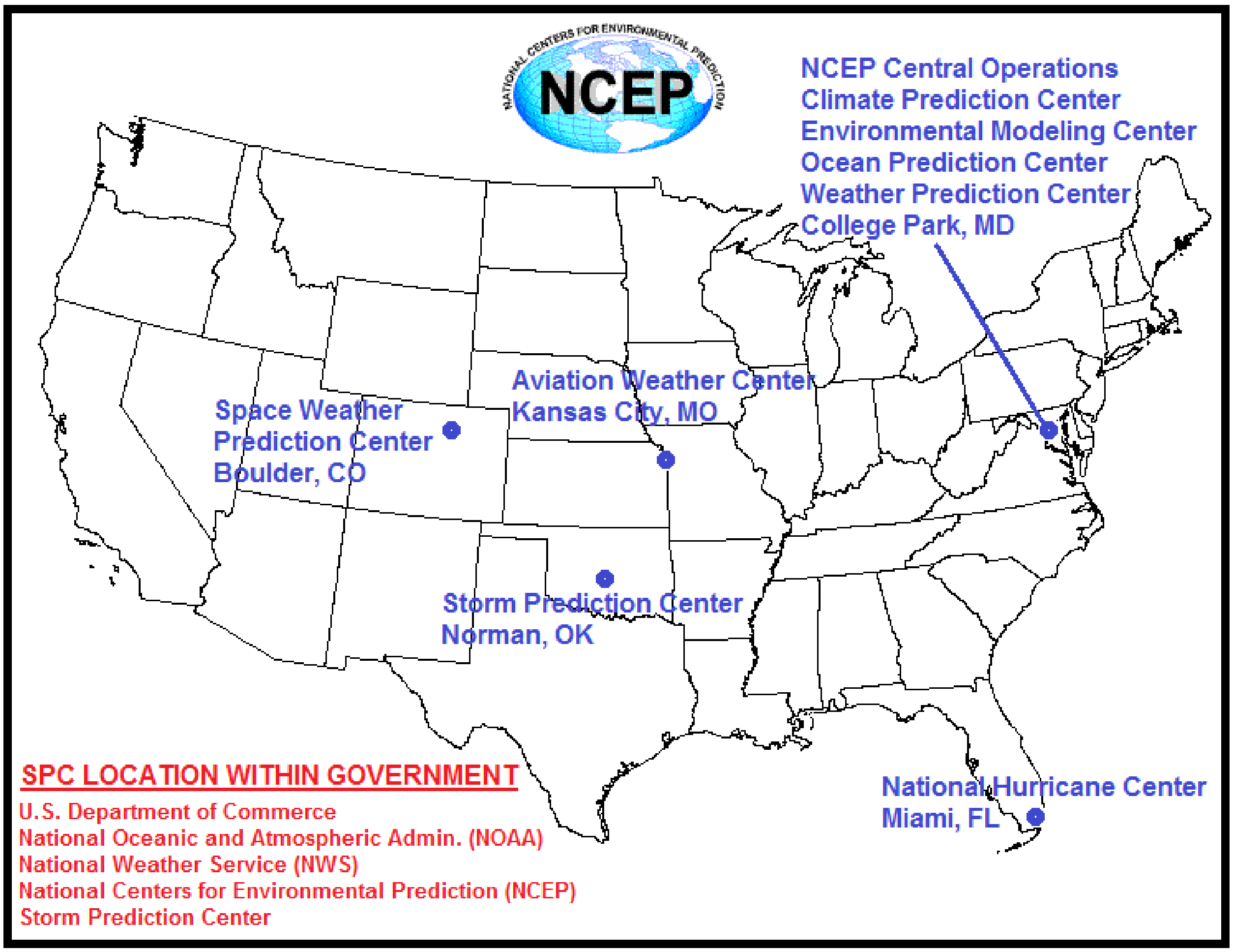

Figure 1: Map of NCEP centers (blue) and hierarchy of SPC within U.S. government (red text). *Background map courtesy U.S. Census Bureau.*

[1] *Corresponding author address:* Roger Edwards, Storm Prediction Center, National Weather Center, 120 Boren Blvd #2300, Norman, OK 73072; E-mail: roger.edwards@noaa.gov

The SPC has a primary mission of forecasting severe local storms, which represent a substantial hazard to the populace and a negative economic impact. The CONUS has ~1000 tornadoes on average per year; and recent years have seen several violent, deadly tornadoes that produced over $1 billion in damage (e.g., Doswell et al. 2012). Climatologically, the NWS classifies convection as severe, as documented in the SPC database (Schaefer and Edwards 1999), if it produces a tornado, hail ≥1 in (2.5 cm) diameter, or measured or estimated gusts ≥50 kt (25 m s^{-1}). Significant severe weather (Hales 1988) is classified as a tornado rated EF2 on the Enhanced Fujita scale (Edwards et al. 2013), hail ≥2 in (5 cm) diameter, or convective gusts ≥65 kt (33 m s^{-1}). The SPC severe-weather database also includes wind-damage reports, regardless of the responsible windspeed (if known). The SPC issues severe-weather outlooks out to eight days in advance, along with mesoscale discussions and public watches for near-term severe-storm potential. Details on these forecasts appear in section 3. Other forecast functions of the SPC include fire-weather outlooks, general-thunderstorm forecasts, probabilistic thunder outlooks, and mesoscale discussions for hazardous winter weather. Details on other SPC forecasts are provided in section 4. Section 5 summarizes data, maps and publications that are not part of the official forecast suite, but that SPC offers online for the benefit of the meteorological community and the public in general. Section 6 offers a brief look into possibilities for the future of SPC's services.

2. HISTORY of SPC and PRECURSORS

Unless otherwise cited, pre-1999 information here is distilled from Corfidi (1999), who gave a detailed history of the SPC and its predecessors in the twentieth century.

a. The pre-Kansas City era

Recognition of the need for a national forecasting agency devoted to tornadoes (and other severe storms) began in the 1870s, when J. P. Finley of the U.S. Signal Corps developed the first documentation of numerous CONUS tornadoes. He recruited over 2000 volunteers to provide tornado-event information that often included accompanying weather conditions (Galway 1992). From that foundational understanding, Finley attempted to produce "tornado alerts". However, his superiors prohibited those forecasts from being made public, fearing that using the word "tornado" would cause panic. The ban on explicit tornado forecasts lingered until 1938, though inertial avoidance of the word continued in forecasts by the U.S. Weather Bureau (predecessor to NWS) until the 1950s. Meanwhile, understanding of synoptic-scale weather patterns and conditions favorable for tornado-producing thunderstorms increased, both empirically and in the literature (e.g., Showalter and Fulks 1943).

In March 1948, tornadoes struck Tinker Air Force Base, OK, five days apart. Two U.S. Air Force forecasters, E. J. Fawbush and R. C. Miller, investigated weather conditions preceding the first tornado. Using those insights, they correctly forecasted the potential for another tornado on the fifth following day, based on occurrence of a similar pattern. That success led to their development of an Air Force Severe Weather Warning Center (SWWC) at the same base.

Public dissemination of SWCC forecasts created demand that later intensified via a military ban on their public release. This demand ultimately led to a civilian severe-storms forecasting unit of the Weather Bureau in Washington, DC. By March 1952, that unit used temporary forecasters to issue teletype "bulletins" (e.g., Fig. 2) loosely analogous to today's watches. Though success was mixed at first, the Washington unit's "bulletins" verified well enough for a few major springtime tornado events to justify a formal, officially named Severe Weather Unit (SWU) on 21 May 1952. By September 1952, the SWU employed five full-time forecasters working rotating shifts—including nights, weekends and holidays—from March through June. Those were the direct predecessors to today's SPC lead forecasters, each of whose slot in today's shift rotation can be traced to one of the original five SWU forecasters, and who still have most of the responsibility for severe-weather watches (section 3). In January 1953, the SWU began issuing daily discussions of severe-storm potential nationwide—the predecessors to today's SPC day-1 outlooks (section 3).

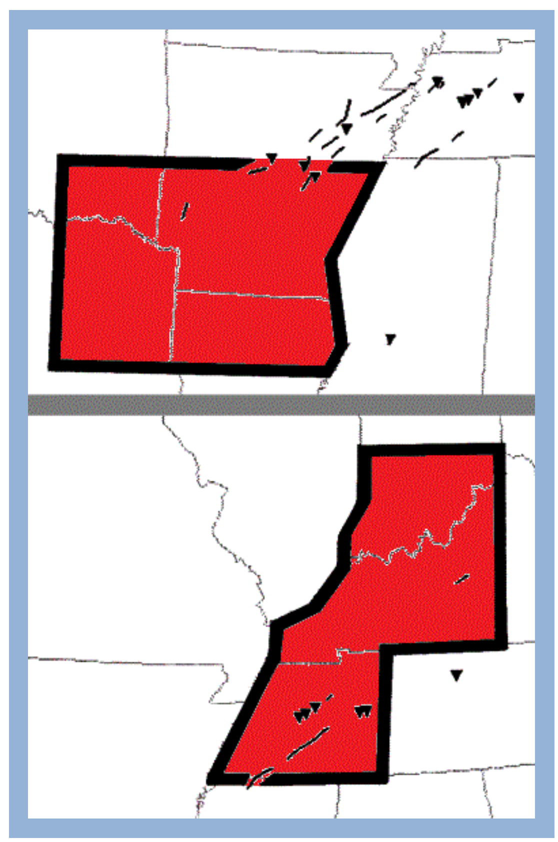

Figure 2: Areal outline (black) and coverage (red) of the first successful SWU tornado "bulletins" (watches). Top: 1800 UTC 21 March 1952; bottom: 0330 UTC 22 March 1952. Triangles and paths denote tornado locations during valid times. Adapted from Fig. 4 of Corfidi (1999).

Figure 3: Buildings housing SELS and SPC: a) Federal Building, 911 Walnut St., Kansas City (1955–1966), looking east; b) Federal Building, 601 E. 12th St., Kansas City (1966–1996), looking southeast; c) NSSL, 1313 Halley Cir., Norman (1996–2006), looking northeast; d) National Weather Center, 120 D. L. Boren Blvd., Norman (2006-present), looking southwest. *Photo credits: (a,b) SPC archives; (c), NSSL; (d) R. Edwards.*

b. SELS and NSSFC in Kansas City

After a series of extraordinarily destructive and deadly tornadoes in 1953, the SWU division was renamed the Severe Local Storms (SELS) unit. SELS added researchers and chartists, then moved to Kansas City, MO, in 1954. Kansas City was a more strategically advantageous location for SELS, being: 1) a major teletype switching node, 2) located in a more tornado-prone part of the U.S., and 3) the location of an existing Weather Bureau office. After about a year at the Kansas City Municipal Airport near downtown, SELS occupied part of the 7th floor of the former Federal Building at 911 Walnut St (Fig. 3a). A centrally mounted rooftop radar tower formed the tallest part of that structure—now re-addressed as 909 Walnut, minus the radar, and holding the status of Missouri's tallest residential building.

In 1966, the SELS unit relocated to the 17th floor of a newly constructed federal facility at 601 E. 12th St. (Fig. 3b)—a building still occupied by other U.S. governmental offices today. SELS grew through the 1960s, 1970s and 1980s, becoming part of a larger office known as the National Severe Storms Forecast Center (NSSFC). The NSSFC also contained a National Public Service Unit (NPSU) and absorbed a satellite-meteorology unit, the Satellite Field Services Station (SFSS). In 1978, NSSFC developed an operational aviation-weather forecasting branch responsible for issuing convective significant meteorological (SIGMET) advisories for aviators; this expanded its forecast suite over time and became known as the National Aviation Weather Advisory Unit (NAWAU). During the early 1990s, a series of personnel moves and budgetary decisions removed the SFSS satellite-interpretation messages and caused the unit to evolve into a mesoscale desk primarily responsible for the mesoscale discussions.

In the mid 1990s, as part of the NCEP reorganization, the NPSU officially disbanded. Its non-technical national weather summary evolved into a hazardous weather update (also a plain-language product) with the move to Norman.

In addition to researchers employed by NSSFC's Techniques Development Unit (TDU), operational forecasters in Kansas City became involved in applied research, including representation at severe-storms conferences and peer-reviewed papers in atmospheric-science journals. This tradition of active SELS participation in storm research has continued since, with numerous formal and informal publications produced at least in part by the forecast staff. The TDU, forerunner of today's SPC Scientific Support Branch (SSB), also provided both software and hardware expertise and maintenance for the growing prevalence of computers in the analysis and forecasting process. Still, hand analysis of surface and upper-air charts remained an important foundational part of the forecasting process (e.g., Sanders and Doswell 1995). The practice continues today (e.g., Fig. 4), as a means to diagnose subtleties of features crucial to severe-weather potential that still escape automated analyses, and for optimal conceptualization of a forecast's base state.

By the early 1990s, scientific understanding of conditions favorable for severe storms had advanced enough for SPC forecasts to include detailed insight on storm environments and behavior (Ostby 1992; 1999). This included the fundamental principle of ingredients-based forecasting (e.g., Doswell 1987; Johns and Doswell 1992; Moller 2001)—the necessary ingredients for organized severe weather being moisture, instability, (mechanisms for) lift, and vertical wind shear. Expected juxtapositions and magnitudes of these ingredients, in space and time, still form the fundamental basis for SPC forecasts of severe-storm risk.

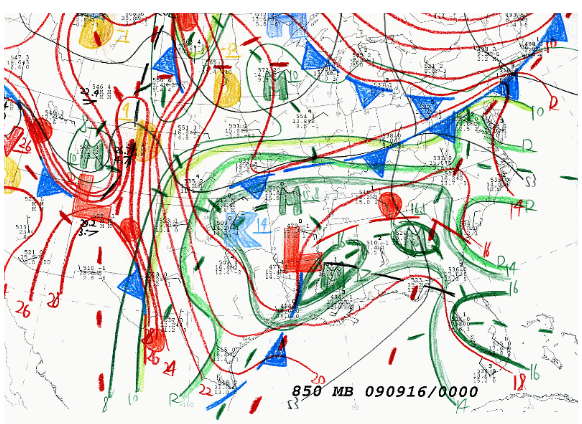

Figure 4: Example of operational SPC hand analysis on an 850-hPa chart, 0000 UTC 16 September 2009, with conventional synoptic features drawn. Isohypses in black (dam), isotherms in red (°C), isodrosotherms in green (°C), dewpoint maxima (minima) marked "M" ("D"). Thermal minimum marked "K". Moist (green) and thermal (red) axes represented by thick, loosely dashed lines.

c. SPC in Norman

In 1995, as part of a broader modernization and restructuring in NWS and NCEP, SELS was renamed SPC. This occurred in anticipation of its 1996 move to Norman, OK, to share a facility with the National Severe Storms Laboratory (NSSL), whose formative component unit, the National Severe Storms Project, had been consolidated with a radar lab in Norman in 1964. SPC occupied part of the ground floor of a two-story NSSL building (Fig. 3c) constructed in the early 1970s, and located adjacent to Max Westheimer airfield.

The NAWAU remained in Kansas City as the AWC, subsequently relocating to suburban quarters near the Kansas City International Airport. By that time, SPC was issuing multiple day-1 outlooks, day-2 outlooks, watches, mesoscale discussions, the hazardous-weather update (later discontinued), and several compilations of severe-storm reports. That output underwent net growth in Norman to encompass the full set of convective and fire-weather products described in the sections 3 and 4. The NPSU in Kansas City evolved into a hazardous weather update desk in Norman via that product and a few common staffers. That desk was the forerunner to the current "mesoscale assistant" group that assumed CONUS fire-weather forecasting duties in 1998, along with assisting in the convective forecasts.

In 2006, SPC and NSSL moved into a new edifice on the University of Oklahoma (OU) campus, the National Weather Center (Fig. 3d), which also contains the OU School of Meteorology, Norman NWS Forecast Office, NWS Warning Decision Training Branch (WDTB), Oklahoma Climatological Survey (including Oklahoma Mesonet), and several cooperative research institutes.

The SPC (staff listing) includes two divisions: the Operations Branch (forecasters) and the SSB, overseen by a small management staff. Within the Operations Branch, SPC employs 22 full-time forecasters. Five lead forecasters supervise shifts, monitor the hazardous weather situation nationally, issue most watches and some outlooks, and proofread all products. A longstanding SELS philosophy of "two pairs of eyes on every product" continues and helps to ensure high quality and minimize technical errors in each forecast. The ten mesoscale/outlook forecasters issue most outlooks and mesoscale discussions (section 3). Seven mesoscale assistant/fire-weather forecasters perform most general-thunderstorm forecasting, all fire-weather outlooks, and many mesoscale discussions and watch-status reports.

The SSB employs hardware and software experts who maintain and upgrade computer-systems hardware and programs that enable forecast operations to function, as well as meteorologists who work with forecasters, NOAA Hazardous Weather Testbed (HWT) participants, and other scientists to infuse new techniques into the forecast process. SSB staff also maintain the SPC website, manage numerous datasets useful to both forecasting and research (e.g., the convective-environment climatology described in Schneider and Dean 2008), and perform objective forecast verification. Some SSB meteorologists and SPC managers also fill in for forecast-shift vacancies during times of staffing shortage.

While SPC is a self-contained office within the National Weather Center building, its strong ties and common interests with the other proximal weather organizations led to the HWT in the late 1990s. In the HWT, researchers from NSSL, OU, and other universities join with WDTB trainers, and with forecasters from SPC, other national and international weather centers, NWS offices, and the private sector, for yearly forecast experiments. HWT participants evaluate new numerical models, conduct applied-forecasting trials, and assess new warning techniques and technologies before they become operational. Weiss et al. (2007) and Clark et al. (2012) offer more detailed discussions of HWT activities.

3. CONVECTIVE FORECASTS

Table 1 lists all SPC convective products with valid period, times issued, and summary description. In discussing SPC severe-weather products, we follow the same conceptual model used in the forecasting process—the Snellman (1982) "forecast funnel" (Fig. 5). The SPC diagnoses and predicts an event beginning at longwave to synoptic scales with extended outlooks. With time the focus narrows to the mesoscale, in the form of as-needed discussions and watches. In addition to predicting severe weather associated with midlatitude baroclinic perturbations, SPC coordinates with NHC to forecast tropical cyclone tornadoes (Edwards 1998; 2012) across the appropriate parts of both centers' guidance packages. SPC does not issue warnings or local storm reports for tornadoes and severe thunderstorms; those are the responsibility of the local NWS offices. The associated presentation for this conference contains some graphic and text examples of the forecast products summarized here, in addition to discussion of SELS and SPC history.

a. Convective outlooks

SPC issues scheduled convective outlooks for severe storms as a whole, valid 2–8 days prior, then specific severe hail, wind and tornado probabilities for the current day. With temporal proximity to an event, outlooks necessarily incorporate less synoptic-scale numerical model guidance, and more input from both diagnostic data and short-fused, high-resolution models.

Table 1. SPC convective forecast products, as of January 2015. Hyperlinks go to the dedicated, current web page for that forecast type where examples can be accessed (except for status reports, which are overwritten). All times UTC. A convective day is defined as 1200-1159 UTC. Changes in UTC product deadlines between Daylight Savings Time (DT) and Standard Time (ST) are specified. TC stands for tropical cyclone.

SPC PRODUCTS	**VALID PERIOD**	**TIME(S) ISSUED (UTC)**	**EVENT COVERAGE**
Day-4–8 Severe Outlook	Fourth through eighth future convective day	0900 for DT, 0830 for ST	Lines representing 15% and 30% probability of any severe weather; brief meteorological discussion. No general- thunder line.
Day-3 Convective Outlook	Third future convective day	0730 for DT, 0830 for ST	Categorical and probability lines for all severe weather collectively according to Fig. 6, with technical discussion. Categorical slight risk invoked at 5% total-severe probabilistic threshold *only if valid entirely for TC tornadoes*. No high risk. General (non-severe) thunderstorm line begins on day 3.
Day-2 Convective Outlooks	Second future convective day	0600 for DT, 0700 for ST; 1730	As with day 3, except high risks are permitted (but rare).
Day-1 Convective Outlooks	Upcoming (for 0600 issuance) or ongoing convective day	0600, 1300, 1630, 2000, 0100	Categorical for all severe weather collectively, triggered by event-specific probabilities for tornado, wind and hail (Fig. 6). Accompanied by detailed, sectional discussion with synopsis.
Mesoscale Discussion	30 min to 3 h	As needed, before and during watches	Text discussion of mesoscale threat and either ongoing watch(es) or probability for new watch issuance. Graphic areal outline.
Severe Thunderstorm or Tornado Watch	Up to 12 h	As needed	Aviation and public watch products and affected county listing. Tornado probability for entire watch area dictates its category.
Watch Status Report	Up to 1 h	20-40 min past each hour during watches	Lists counties remaining in threat area covered by associated watch, defines remaining severe-weather threat to the right of a line.

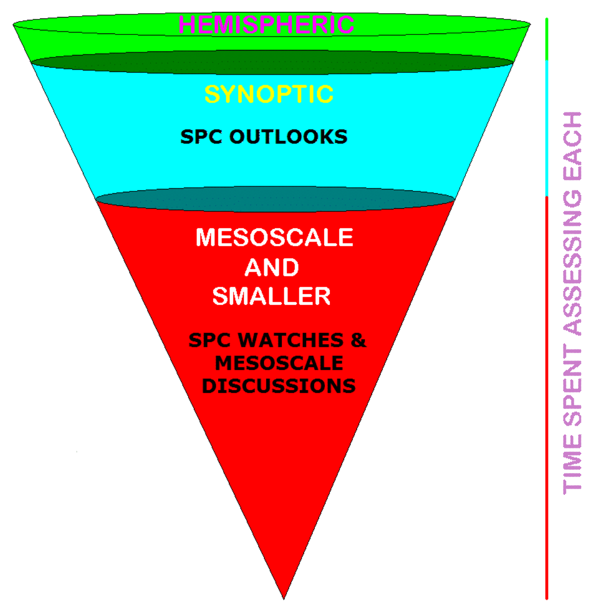

Figure 5: How the "forecast funnel" (Snellman 1982) concept applies to SPC products. There is some overlap; for example, outlooks often discuss mesoscale features on day 1, and watches and mesoscale discussions depend on input from the synoptic scale.

The convective day is defined from 1200–1159 UTC, including local overnight and pre-dawn hours across the CONUS. The discontinuity conveniently falls near the climatological morning minimum in severe-weather potential over most of the country. Probabilities (Fig. 6) are valid for a 25-mi (40-km) radius from a point, and were derived from historical severe-storm reports and associated SELS and SPC categorical outlooks. Probabilities numerically define outlooks for the meteorological audience, and make them more straightforward to verify objectively against actual severe-weather reports. Individual NWS offices infuse SPC outlook guidance into their own gridded forecasts. Meanwhile, the marginal, slight, enhanced, moderate, and high categorical risks remain tied to specific hazard probabilities and are offered as a relative indicator of threat for use by public, media and emergency-management audiences. Figure 6 summarizes specifications for day-1–3 convective outlooks.

Day-4–8 outlooks feature a short text discussion and a daily graphic that contains a categorical severe-weather outlook line for any day(s) where an area of ≥15% risk can be forecast for severe weather. Mesoscale processes not predictable at such time ranges, along with other prognostic uncertainties involved in lower-end severe events, preclude use of lower unconditional probabilities. Day-3 outlooks likewise are driven probabilistically, but contain both categorical and probabilistic maps, along with a general (non-severe) thunderstorm area that outlines a ≥10% probability (on a 40-km grid) for cloud-to-ground (CG) lightning strikes. These outlooks also contain a somewhat longer text discussion. Because of uncertainties inherent to severe-storm forecasting that far in advance, day-3 outlooks cannot be issued with total-severe probabilities supporting a high risk; however, the otherwise similar day-2 outlooks can.

By day 1, sufficiently large specific probabilities of either damaging wind or tornadoes can support a high risk (Fig. 6). Though the most complex SPC product, the day-1 outlook also is consistently the most popular, in terms of SPC website hits. This likely is because it contains the most information: both categorical and probabilistic maps of specific severe-storm hazards (hail, wind, tornado), with a public headline and technical discussion. The discussions tend to be detailed and lengthy for major events, offering a great deal of meteorological insight into synoptic to mesoscale processes causing the threats. The day-1–3 outlooks also include a general thunderstorm area thresholded to ≥10% cloud-to-ground lightning probabilities. As accessories to the day-1 outlooks, enhanced thunderstorm forecasts give temporal breakdowns of probabilistic cloud-to-ground lightning potential within the day-1 period, including 40% and 70% areas within the 10% lines as necessary.

b. Mesoscale discussions

As a severe-weather event gets closer in time, uncertainty usually diminishes in both time and space, and the juxtaposition of favorable ingredients often becomes more apparent[2]. Boundaries that act as foci for severe-thunderstorm development and maintenance also become more evident, through both subjective and objective diagnostics in combination with short-term numerical guidance. High-resolution, convection-allowing models, such as those developed and refined via the HWT, are a recent operational tool that allows forecasters to gauge the potential for both convection initiation and mode (e.g., supercell, quasi-linear, clustered, etc., after Smith et al. 2012).

Once confidence in a scenario is sufficient that potential for a watch can be estimated probabilistically, SPC issues a mesoscale discussion (MD). The MD, an unscheduled product issued as necessary, contains textual and graphical components, the latter outlining an area and offering a map of the threat. The text states the probability of a watch, headlines the area affected, and gives detailed meteorological reasoning. Probabilities are related to categorical watch potential as follows: unlikely (5% or 20%), possible (40% or 60%), or likely (80% or 95%). Once a watch has been issued, MDs provide updated information on the changing scenario every 2–3 h in the watch area, and provide insight into the potential for additional watches. The SPC typically issues around 2000 MDs per year.

c. Watches and status reports

The severe-weather watch is the most urgent forecast product of the SPC, a notice that severe storms could develop or move into the affected area

[2] Sometimes, however, the onset of mesoscale influences in the forecast process makes the threat *less* clear as an event draws near (Evans et al. 2008).

Day 1 Outlook Probability	TORN	WIND	HAIL
2%	MRGL	Not Used	Not Used
5%	SLGT	MRGL	MRGL
10%	ENH	Not Used	Not Used
10% with Significant Severe	ENH	Not Used	Not Used
15%	ENH	SLGT	SLGT
15% with Significant Severe	MDT	SLGT	SLGT
30%	MDT	ENH	ENH
30% with Significant Severe	HIGH	ENH	ENH
45%	HIGH	ENH	ENH
45% with Significant Severe	HIGH	MDT	MDT
60%	HIGH	MDT	MDT
60% with Significant Severe	HIGH	HIGH	MDT

Day 2 Outlook Probability	Combined TOR, WIND, HAIL
5%	MRGL
15%	SLGT
15% with Significant Severe	SLGT
30%	ENH
30% with Significant Severe	ENH
45%	ENH
45% with Significant Severe	MDT
60%	MDT
60% with Significant Severe	HIGH

Day 3 Outlook Probability	Combined TOR, WIND, HAIL
5%	MRGL
15%	SLGT
15% with Significant Severe	SLGT
30%	ENH
30% with Significant Severe	ENH
45%	ENH
45% with Significant Severe	MDT

Figure 6: Categorical conversions of probabilistic SPC outlooks, as labeled. TORN is tornado, MRGL is marginal, SLGT is slight, ENH is enhanced, and MDT is moderate. "Significant severe" (Hales 1988) represents a 10% probability for tornadoes rated at least EF2, hail ≥2 in (5 cm), and/or thunderstorm gusts ≥50 kt (25 m s^{-1}).

within the next few hours. Watches serve as the preparatory step to local NWS warnings. The SPC usually issues 700–1000 watches y^{-1}. Watches typically cover an area ~25 000 mi^2 (64 750 km^2) but can vary greatly from that average, depending on the size of land area threatened, the duration of the risk and the speed of translation of the parent weather system. The watch has components for public, aviation and meteorological audiences, and typically is valid for 6–9 h after issuance. Watches for unusually steady-state or slowly translating severe-weather situations, such as slow-moving tropical cyclones, can last up to 12 h.

Before issuance, watches are collaborated with local NWS offices. When the lead forecaster (or designee) decides a watch is necessary, a list of affected counties is drawn on-screen and converted to an internal bulletin, which is in turn transmitted to the affected NWS offices. SPC then uses a conference call to finalize whether that watch will be issued, and if so, its dimensions in space and time, as well as its type (tornado or severe thunderstorm). If still deemed necessary, the watch is transmitted once collaboration is done. A legacy polygon (known in SELS days as a "watch box") still is sent to approximate the affected area for aviation purposes.

Watch configuration is both an art and a science—the science part using situational meteorology and the art being known colloquially as "boxology", or strategically orienting watches to both fit the evolving scenario and minimize spatial complexity. For example, it usually is desirable to have either one watch in a local NWS jurisdiction, or if two are needed, to have them expire simultaneously. However, purely meteorological considerations (e.g., a substantially longer-lasting or more tornadic threat in one corner of a local NWS area that would require later watch expiration or a different "watch color") override expediency.

Watch type is tied to the probability of a tornado anywhere in the watch. Probabilities sufficient to drive the tornado category are assigned when the watch forecaster expects at least one strong (≥EF2[3]) tornado or >2 tornadoes of any rating. During "high risk" and some "moderate risk" outlook scenarios, SPC may issue a "particularly dangerous situation" (PDS) watch. Usually, PDS watches are for threats of multiple strong to violent tornadoes (EF2–EF5); though PDS severe thunderstorm watches can be issued for extreme derecho environments (Johns and Hirt 1987; Evans and Doswell 2001). Although local NWS offices are responsible for clearing counties from watches, or cancelling them completely, SPC provides hourly status reports during original watch valid times as guidance, suggesting areas of remaining threat. Local NWS offices (usually in coordination with SPC) can extend watches in space and/or ≤2 h of time.

[3] This describes the rating of tornado damage by the Enhanced Fujita (EF) scale, which indicates but cannot definitively prove tornado intensity. See Edwards et al. (2013) for a history and description of the EF scale.

4. OTHER SPC FORECASTS

a. Fire-weather outlooks

In response to a void in nationwide forecasting for conditions suitable for the spread of wildfires, and a lack of a national center specifically devoted to fire weather, SPC began issuing experimental fire-weather outlooks in 1998. The mesoscale assistant forecasters prepare these outlooks. Operational day-1 through day-3 fire-weather outlooks began in 2001; the suite (Table 2) now includes day-3–8 forecasts analogous to the day-4–8 convective outlooks. As with the convective outlooks, fire-weather outlooks include graphical and text components, and become more specific and more diagnostically driven with temporal proximity to the forecast period.

Fire-weather outlooks are focused on outlining probabilistically driven categorical "critical" areas, where forecast meteorological conditions indicate rapid growth of wildfires is possible. The day-3–8 fire-weather outlooks can contain critical areas for: 1) Dry thunderstorms (producing little or no rain), with ≥40% probability of dry thunderstorms where dry fuels exist within ≈12 mi (20 km) of a point during the 24- h period of the indicated day; and/or 2) ≥70% probability of strong winds, low RH, and warm temperatures concurrent for at least 3 h, where dry fuels exist. Antecedent drought conditions are considered when contemplating the inclusion of a marginal situation in an outlook area.

Day-2 and day-1 fire-weather outlooks may include all the critical areas of the day-3 portion of the extended outlook. In addition, day-2 and day-1 fire-weather outlooks can include an extremely critical area, the highest threat level of wildfire starts and spreads in SPC products. Subcritical areas are assigned an "elevated" risk category when conditions are somewhat favorable, but probabilities are too low or conditional to draw a categorical risk area.

b. Winter-weather MDs

Although most winter-weather forecasting is the responsibility of the WPC or local NWS offices, mesoscale discussions for hazardous winter-storm conditions began in SELS and continue in the current SPC forecast suite. These discussions cover the mesoscale aspects (parts of states and out to ≈6h) of heavy snow, blizzards, freezing rain, and mixed winter precipitation. Winter-weather MDs are issued when the forecaster expects any of the following:

- 1) ≥2 h of snow rates ≥1 in h^{-1} (2.5 cm h^{-1}) at elevations 4000 ft (1219 m) MSL, or of rates ≥2 in h^{-1} (5 cm h^{-1}) between 4000–8000 ft (1219–2438 m) MSL;
- 2) freezing-rain rates 0.05 in 3 h^{-1} (0.04 cm h^{-1});
- 3) Blizzard conditions—defined as snow reducing visibility to <0.25 mi (0.4 km) with ≥35-mph (15.6-m s^{-1}) windspeeds.

Climatologically or geographically rare events also may justify an MD below those criteria at forecaster discretion.

Table 2. SPC fire-weather forecast products, as of January 2015. Hyperlinks go to the dedicated web page for that forecast. All times UTC. A fire-weather day is defined the same as a convective day. Changes in UTC product deadlines between Daylight Savings Time (DT) and Standard Time (ST) are specified.

SPC PRODUCTS	VALID PERIOD	TIME(S) ISSUED	EVENT COVERAGE
Day-3–8 Fire Weather Outlook	Third through eighth future fire-weather day	2200	Categorical and probability lines for dry thunderstorms and strong winds/low RH/warm temperatures where dry fuels exist. Categorical critical designation invoked at 40% threshold for dry thunderstorms and 70% for strong winds/low RH/warm temperatures.
Day-2 Fire Weather Outlook	Second future fire-weather day	1000, 2000	Categorical lines for dry thunderstorms (isolated and scattered) and strong winds/low RH/warm temperatures (elevated, critical, and extremely critical) where dry fuels exist.
Day-1 Fire Weather Outlooks	Upcoming (for 0900 issuance) or ongoing fire-weather day	0900 for DT, 1000 for ST; 1700	Same as for day 2.

5. NON-OPERATIONAL SPC SERVICES

Digital archives of several SPC forecast products are available online from 2004 onward. In addition to scheduled and as-needed forecasts, the SPC offers storm reports in multiple formats and time periods. Daily severe-weather report listings and maps are updated throughout the convective day, from local storm reports sent by NWS offices. These initial reports consist of raw data, commonly containing errors or duplications. As such, daily SPC report logs should be considered preliminary only. Preliminary storm reports that are later confirmed and quality-controlled are submitted by local NWS offices into the final NWS *Storm Data* dataset. As detailed in Schaefer and Edwards (1999), *Storm Data* tornado reports are segmented by county, since they are used to verify warnings and watches. However, SPC connects the segmented tornado tracks into single-tornado listings, as part of the 1950–2012 SPC severe weather database. The same data also are available as GIS shapefiles. Even the final data should be used with great caution; historical severe-weather data are known to be fraught with inconsistencies, inaccuracies and secular artifacts (e.g., Verbout et al. 2006). Many severe-weather events from January 2000 onward also have been archived at SPC with summary meteorological information. The SPC warning-coordination meteorologist offers a diverse website with numerous other types of severe-weather occurrence information, charts and maps (e.g., Fig. 7).

Both research- and forecasting-related resources for the rest of the meteorological community can be found on the SPC website. Throughout its history, SPC and SELS have been very active in contributing operationally meaningful research to the science of severe local storms. Over sixty formal papers and >100 conference articles are available on the SPC publications page as of February 2015, with more projects underway. All of these papers, and the other web content that follows, are in the public domain. These publications include such commonly used tools developed by SPC staff as the lifted index (Galway 1956), the supercell composite and significant tornado parameters (Thompson et al. 2003), and effective measures of bulk shear and storm-relative helicity (Thompson et al. 2007). Several other forms of educational information appear on the SPC website, including frequently asked questions answered regarding the SPC itself, as well as tornadoes and derechoes. Tornado safety information and the EF scale also are covered.

Diagnostic forecasting tools for the conterminous U.S., developed wholly or in part at the SPC, are available online, including: daily U.S. upper-air charts, skew *T*–log*p* representations and parameters of observed soundings, real-time automated mesoanalyses (Bothwell et al. 2002) in eight overlapping sectors, a CONUS-wide climatology of observed soundings, toggled composite maps, an interactive tornado-environment map, and a set of composite-analysis sectors for fire-weather forecasters.

Numerical model-based guidance offered by SPC includes products derived from the Short-range Ensemble Forecast (SREF) system (Du et al. 2009) and an interface for parameters from the High-Resolution Rapid Refresh (HRRR, Alexander et al. 2010; Clark et al. 2012) model. The SPC uses the HRRR and ensemble model output from SREF and other systems routinely in forecast operations, and SPC scientists have been leaders in developing and adapting SREF guidance for this purpose (e.g., Guyer and Bright 2008). The results of those efforts are online at SPC, in the form of graphical SREF forecasts tailored to severe-storms, winter-weather and fire-weather concerns. SPC offers SREF-based plume diagrams as well. Aside from the HRRR, several high-resolution, explicitly convection-allowing models can be assembled into an ad-hoc ensemble for operational use as well. SPC forecasters use the resulting Storm-scale Ensemble of Opportunity (SSEO; Jirak et al. 2012) to aid in timing convective initiation, as well as indicating potential storm mode. The SPC also provides SSEO products online.

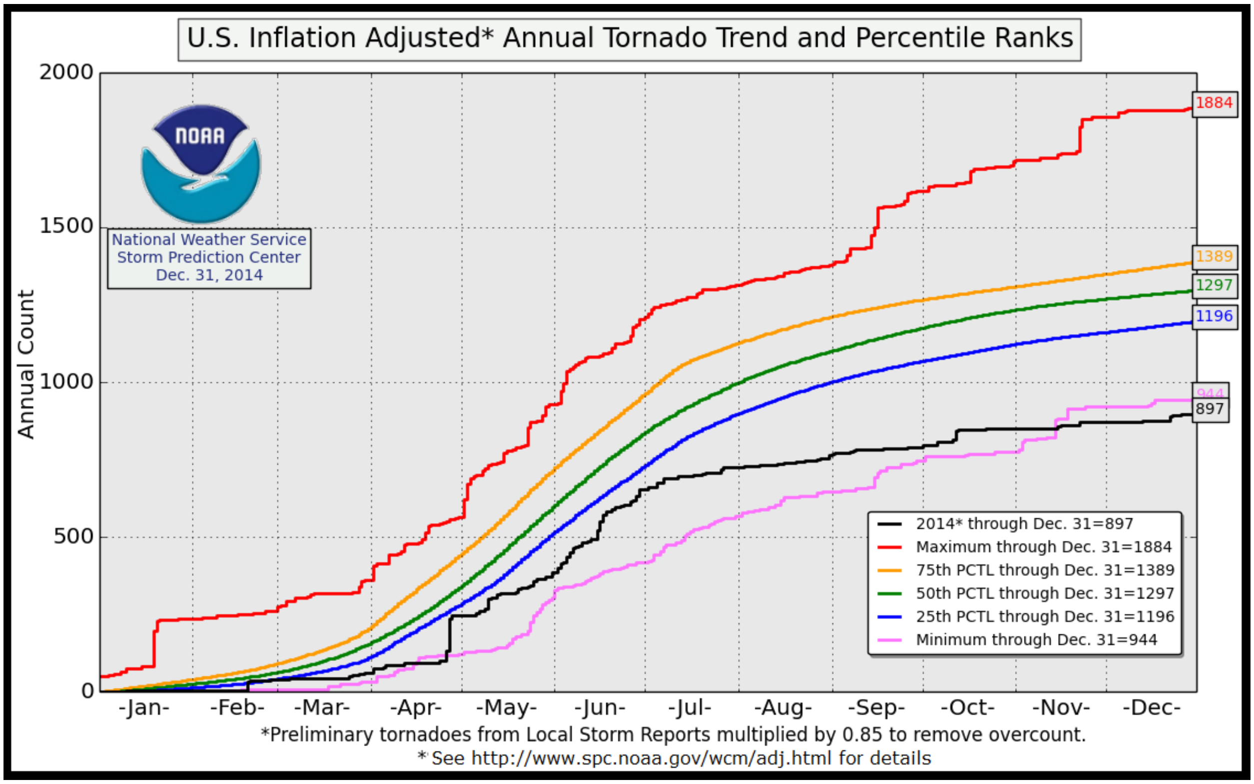

Figure 7: Annual tornado-trend graph produced by the warning-coordination meteorologist and supplied online, as an example of non-operational SPC data services. Graph is a plume diagram of accumulated nationwide tornado reports for the maximum year of record (red), minimum prior to 2014 (magenta), preliminary 2014 record (black), and percentiles (per legend) based on regression equations covering the 1954–2007 seasons.

6. SUMMARY AND FUTURE

The SPC offers a wide variety of forecasts, diagnostic tools and educational information, mainly regarding severe local storms and fire weather. The SPC and its predecessors have been pioneers and innovators in severe-weather forecasting for over 60 years, and plan to remain so in the future. Collocated with a diverse group of meteorological organizations in the National Weather Center, SPC meteorologists and other scientists collaborate often to improve prediction of hazardous weather, including via the HWT.

Through HWT, SSB and forecaster research, and other professional collaborations, SPC products (forecasts and non-operational offerings) will evolve to serve a diverse consumer base with multifaceted needs for severe- and fire-weather information. High-resolution numerical guidance tested in the HWT will continue to assume a greater influence in the forecasting process as its skill demonstrably improves. Meanwhile, NWS-wide efforts to infuse social-science concepts into forecast services, as well as to link efforts more intensively with emergency managers and other nonmeteorological disciplines (Lindell and Brooks 2013), will be applied at the SPC. The result, in the form of survey-driven input and direct research collaboration, should help SPC to define its audiences better and refine its forecasts to target their needs.

ACKNOWLEDGMENTS

The entire staff of the SPC and SELS—current and past—has contributed to this effort through published contributions to the science, collective forecasting experience passed down through generations, and successive advancements in techniques development (hardware and software). SPC collaborations throughout NWS, with NSSL and other researchers, with academia, and with the entire spectrum of non-NWS consumers of severe- and fire-weather information, also have contributed. All participants in that process, though too numerous to name individually, have helped to build the SPC of today and tomorrow. We thank the Catalonian Meteorological Association (Associació Catalana de Meteorologia/ACAM) of Barcelona for hosting an invited presentation in 2013 that formed the nucleus for this one. Israel Jirak (SPC SOO) provided helpful reviews of various stages of this documentation.

REFERENCES

Alexander, C. R., S. S. Weygandt, T. G. Smirnova, S. Benjamin, P. Hofmann, E. P. James, and D. A. Koch, 2010: High Resolution Rapid Refresh (HRRR): Recent enhancements and evaluation during the 2010 convective season. Preprints, *25th Conf. on Severe Local Storms*, Denver, CO, Amer. Meteor. Soc., 9.2.

Bothwell, P. D., J. A. Hart, and R. L. Thompson, 2002: An integrated three-dimensional objective analysis scheme in use at the Storm Prediction Center.

Preprints, *21st Conf. on Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., JP3.1.

Clark, A. J., and Coauthors, 2012: An overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bull. Amer. Meteor. Soc.*, **93**, 55–74.

Corfidi, S. F., 1999: The birth and early years of the Storm Prediction Center. *Wea. Forecasting*, **14**, 507–525.

Doswell, C. A. III, 1987: The distinction between large-scale and mesoscale contribution to severe convection: A case study example. *Wea. Forecasting*, **2**, 3–16.

——, G. W. Carbin, and H. E. Brooks, 2012: The tornadoes of spring 2011 in the USA: An historical perspective. *Weather*, **67**, 88–94.

Du, J., and Coauthors, 2009: NCEP Short-Range Ensemble Forecast (SREF) system upgrade in 2009. Preprints, *19th Conf. on Numerical Weather Prediction/23rd Conf. on Weather Analysis and Forecasting*, Omaha, NE, Amer. Meteor. Soc., 4A.4.

Edwards, R., 1998: Storm Prediction Center forecast support for landfalling tropical cyclones. Preprints, 23rd Conf. on Hurricanes and Tropical Meteor., Dallas, TX, Amer. Meteor. Soc., 53–56.

——, 2012: Tropical cyclone tornadoes: A review of knowledge in research and prediction. *Electronic J. Severe Storms Meteor.*, **7** (6), 1–61.

——, J. G. LaDue, J. T. Ferree, K. Scharfenberg, C. Maier, and W. L. Coulbourne, 2013: Tornado intensity estimation: Past, present, and future. *Bull. Amer. Meteor. Soc.*, **94**, 641–653.

Evans, J. S., and C. A. Doswell III, 2001: Examination of derecho environments using proximity soundings. *Wea. Forecasting*, **16**, 329–342.

——, C. M. Mead and S. J. Weiss, 2008: Forecasting the Super Tuesday tornado outbreak at the SPC: Why forecast uncertainty does not necessarily decrease as you get closer to a high impact weather event. Preprints, *24th Conf. on Severe Local Storms*, Savannah, GA, 3A.2.

Galway, J. G., 1956: The lifted index as a predictor of latent instability. *Bull. Amer. Meteor. Soc.,* **37,** 528–529.

——, 1992: Early severe thunderstorm forecasting and research by the United States Weather Bureau. *Wea. Forecasting*, **7**, 564–587.

Guyer, J. L., and D. R. Bright, 2008: Utility of Short-range Ensemble Forecast (SREF) guidance for forecasting the development of severe convection. Preprints, 24th Conf. Severe Local Storms, Savannah, GA, 13A.1.

Hales, J. E. Jr., 1988: Improving the watch/warning system through use of significant event data. Preprints, *15th Conf. on Severe Local Storms*, Amer. Meteor. Soc., Baltimore, MD, 165–168.

Jirak, I. L., S. J. Weiss, and C. J. Melick, 2012: The SPC Storm-scale Ensemble of Opportunity: Overview and results from the 2012 Hazardous Weather Testbed spring forecasting experiment. Preprints, 26th Conf. Severe Local Storms, Nashville, TN, P9.137.

Johns, R. H., and W. D. Hirt, 1987: Derechoes: Widespread convectively induced windstorms. *Wea. Forecasting*, **2**, 32–49.

——, and C. A. Doswell III (1992): Severe local storms forecasting. *Wea. Forecasting*, **7**, 588–612.

Lindell, M. K., and H. E. Brooks, 2013: Workshop on Weather Ready Nation: Science imperatives for severe thunderstorm research. *Bull. Amer. Meteor. Soc*., **94**, ES171–ES174.

Moller, A. R., 2001: Severe local storms forecasting. *Severe Convective Storms, Meteor. Monogr.*, No. 50, Amer. Meteor. Soc, 433–480, doi: 10.1175/0065-9401-28.50.433.

Ostby, F. P., 1992: Operations of the National Severe Storms Forecast Center. *Wea. Forecasting*, **7**, 546–563.

——, 1999: Improved accuracy in severe storm forecasting by the Severe Local Storms Unit during the last 25 years: Then versus now. *Wea. Forecasting*, **14**, 526–543.

Sanders, F., and C. A. Doswell III, 1995: A case for detailed surface analysis. *Bull. Amer. Meteor. Soc.*, **76**, 505–521.

Schaefer, J. T., and R. Edwards, 1999: The SPC tornado/severe thunderstorm database. Preprints, *11th Conf. on Applied Climatology*, Amer. Meteor. Soc., Dallas, TX, 603–606.

Schneider, R. S., and A. R. Dean, 2008: A comprehensive 5-year severe storm environment climatology for the continental United States. Preprints, *24th Conf. on Severe Local Storms*, Savannah, GA, 16A.4.

Showalter, A. K., and J. R. Fulks, 1943: Preliminary report on tornadoes. U.S. Weather Bureau, Washington, DC, 162 pp.

Smith, B. T., R. L. Thompson, J. S. Grams, C. Broyles, and H. E. Brooks, 2012: Convective modes for significant severe thunderstorms in the contiguous United States. Part I: Storm classification and climatology. *Wea. Forecasting*, **27**, 1114–1135.

Snellman, L. W., 1982: Impact of AFOS on operational forecasting. Preprints, *Ninth Conf. on Weather Forecasting and Analysis*, Seattle, WA, Amer. Meteor. Soc., 13–16.

Thompson, R. L., R. Edwards, J. A. Hart, K. L. Elmore, and P. M. Markowski, 2003: Close proximity soundings within supercell environments obtained from the Rapid Update Cycle. *Wea. Forecasting,* **18,** 1243–1261.

——, C. M. Mead, and R. Edwards, 2007: Effective storm-relative helicity and bulk shear in supercell thunderstorm environments. Wea. Forecasting, **22**, 102–115.

Verbout, S. M., H. E. Brooks, L. M. Leslie, and D. M. Schultz, 2006: Evolution of the U.S. tornado database: 1954–2003. *Wea. Forecasting*, **21**, 86–93.

Weiss, S. J., and Coauthors, 2007: The NOAA Hazardous Weather Testbed: Collaborative testing of ensemble and convection-allowing WRF models and subsequent transfer to operations at the Storm Prediction Center. Preprints, 22nd Conf. on Weather Analysis and Forecasting/18th Conf. on Numerical Weather Prediction, Salt Lake City, UT, Amer. Meteor. Soc., 6B.4.