Operations of the National Severe Storms Forecast Center

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ABSTRACT

The National Severe Storms Forecast Center in Kansas City, Missouri, is composed of several operational forecasting units, all national in scope. It includes the Severe Local Storms Unit (SELS), the National Aviation Weather Advisory Unit (NAWAU), and a Techniques Development Unit (TDU). Within SELS there is a synoptic interpretation message (SIM) section and a mesoscale discussion (MD) section.

The SELS Unit has been in Kansas City since 1954 and is responsible for providing a wide array of products related to severe weather: convective outlooks, public weather statements, mesoscale discussions, status reports, and tornado and severe thunderstorm watches for the 48 conterminous states. SELS is also responsible for preparing a national weather summary. NAWAU provides alerts, nationally, of hazardous weather, known as AIRMETs and SIGMETs, and convective SIGMETs to aviation interests. NAWAU also issues aviation area forecasts. The SIM section prepares a diagnostic interpretative message that incorporates satellite and other information and relates them to model trends. The MD section supports the SELS program by providing short-range updates on developing mesoscale systems.

The Techniques Development Unit has been responsible for working hand in hand with SELS to reap the benefits of applying interactive computer-processing technology, progressively giving the forecaster more effective means to provide improved services. Illustrating these improvements is the fact that severe weather watches have significantly increased in accuracy, especially in handling violent death-dealing tornado situations.

An illustrative example of SELS products is shown for the severe weather outbreak of 15–17 June 1992. The example shows how skillfully this episode, producing 172 tornadoes and 462 other reported severe weather events, was forecast. Emphasis is made of the need for consistent and well-coordinated watches and other advisories when dealing with widespread, rapidly moving, severe weather-producing systems.

1. Introduction

This is one of a series of review articles on the operations of the three national forecasting centers of the National Weather Service. The two previous articles in *Weather and Forecasting* covered the National Meteorological Center (Bonner 1989) and the National Hurricane Center (Sheets 1990). The National Severe Storms Forecast Center (NSSFC) includes the Severe Local Storms Unit (SELS), which is the focal point of severe storm forecasting expertise in the United States. The importance of this role is reflected in the fact that there are more than 800 tornadoes per year that kill nearly 100 people in the United States. A much higher potential death toll exists, given the population density and the lethal power of these storms. It is a tribute to this core of forecasting expertise, as well as National Weather Service offices with warning and preparedness responsibility, the media, emergency managers, and other decision makers, that tornado fatalities in recent years have been reduced by about half.

With its roots originating in the establishment of the SELS unit in Kansas City in 1954, NSSFC has grown steadily in stature and program areas of responsibility over the years. Up until 1978, the only NSSFC programs that were national in scope were SELS and the National Public Service Unit (NPSU). Other programs involving public and aviation forecasting were either local or regional in nature. In 1978, the convective SIGMET (Significant Meteorological Advisories) unit was established, providing hourly bulletins on a national basis to aviation interests concerning hazards due to convective phenomena. In 1982, the National Aviation Weather Advisory Unit (NAWAU) was created, centralizing and consolidating the aviation area forecast programs that had operated out of nine NWS offices (including NSSFC) across the 48 conterminous states. Plans are currently underway to transfer the responsibility for international SIGMETs from the National Meteorological Center to NSSFC. During the 1980s, the Satellite Interpretation Message (SIM) program that had previously provided service to a 21-state area gradually expanded its geographic responsibility and now services the 48 conterminous states and adjacent waters (excluding the tropics). As will be discussed later, all these changes have resulted in resource

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savings for the National Weather Service without sacrificing effectiveness.

Supporting staff at NSSFC includes a computer operator unit to run the day-to-day function of the various computer systems and keep the operational units apprised of their status. Another important support function is provided by a well-trained and highly skilled unit of electronic technicians who contribute necessary maintenance on a widely diverse and complex array of electronic equipment. Finally, a small subsection of SELS prepares a limited national weather summary twice daily for both internal NWS and external users. It summarizes the most significant weather going on across the nation at the time.

2. History of severe local storm forecasting

a. The early days

Some of the first efforts at understanding and forecasting severe local storms in the United States were pioneered by a Signal Corps meteorologist named John P. Finley (Galway 1985). Lieutenant Finley was far ahead of his time, tirelessly researching tornado occurrences to establish techniques for forecasting severe local storms from an extremely limited database. His findings resulted in a list of factors favorable for tornado formation (Schaefer 1986), not unlike some of today's so-called forecast checklists. For example, he recognized as favorable patterns those that included warm moist air advancing from the south being acted upon by cold dry air from the west. He also showed a keen appreciation for climatology by noting preferred geographical areas and conducive times of the year. From this intensive investigation came the start in 1884 of "experimental tornado predictions." After some modest success during that spring, forecasts were permitted to include "violent local storms" in 1885 when tornado development appeared favorable, but use of the word "tornado" was forbidden. The ban was lifted briefly in 1886 but reinstated in 1887 (which remained the policy for many years after). These experimental forecasts were discontinued the following year and while Finley continued his research, there is little evidence to indicate any serious efforts at prediction thereafter. Later study of tornadoes was not confined to the United States. One notable tornado researcher in Europe in the early half of the twentieth century was Johannes Letzmann, whose tornado studies included climatology, damage investigations, and laboratory experiments. Peterson (1992) points out that in many respects Letzmann's work was decades ahead of his time.

b. The modern era

Advances in weather observing systems, particularly the radiosonde, helped to spur renewed interest in severe storm forecasting during the 1940s. The most significant contribution to operational forecasting was brought about by Fawbush and Miller, who, using empirically derived procedures developed from severe weather episodes over the southern plains, correctly forecast a tornado threat for Tinker Air Force Base, Oklahoma, on 25 March 1948, within one week of a prior tornado hit at the base (Bates and Fuller 1986).

Around this same time, the U.S. Weather Bureau (predecessor of the National Weather Service) was making progress in developing an understanding of some of the antecedent conditions associated with tornado and severe thunderstorm development based partly on earlier work by Showalter and Fulks (1943), among others. In March 1952, a group of research forecasters at the Weather Bureau–Air Force–Navy (WBAN) Analysis Center in Washington, D.C., made the weather bureau's first public tornado forecast after several weeks of producing experimental in-house forecasts. An actual full-time operational staff devoted to severe local storm prediction began in May of 1952 and subsequently moved to Kansas City, Missouri, in 1954 (Galway 1989, 1992). Convective outlooks (AC) began in 1953 as severe weather discussions before being renamed in 1955.

Rapid progress has been made during the ensuing years because of new and improving technology, increased understanding of the atmosphere on both synoptic and mesoscales, and the invaluable experience acquired by skilled severe storm forecasters. The advent of the high-speed computer and its application to severe storms forecasting have been of paramount importance in this progress. In particular, the interactive computer processing systems now in operation at NSSFC have enabled the forecaster to diagnose in a much more detailed way the current state of the atmosphere. Such diagnoses and understanding of active atmospheric processes are crucial to the forecast problem, for if one cannot understand what is causing the current weather, it follows that making reasonable forecasts is difficult if not impossible (Doswell and Maddox 1986).

3. Forecast responsibilities and products

a. General

Operational forecasts produced at NSSFC are all national in scope. Severe local storm forecasting by the SELS unit covers the 48 conterminous states, as it has since the unit's inception. Aviation forecasts, including convective SIGMETS, in-flight advisories, and area forecasts, also represent centralized national guidance. Products of these types had previously been prepared on a regional basis at nine different National Weather Service offices. The convective SIGMET portion became a national product emanating from NSSFC in 1978. In-flight advisories and area forecasts became centralized products originating at NSSFC in November 1982. The synoptic interpretation product grew from one that was originally prepared on a regional basis by the National Environmental Satellite Data and Information Service, Satellite Field Services Station (SFSS). This responsibility was eventually transferred to the National Weather Service and now encompasses the nontropic 48 conterminous states and adjacent coastal waters.

b. Severe weather guidance and forecasts

The overall SELS philosophy for forecasting severe convection begins with the large-scale synoptic framework and gradually shifts the focus with time, down toward the mesoscale. The procedures and products issued by SELS are a reflection of that approach. Details of the forecast process and procedures are given by Johns and Doswell in a companion article (1992) as well as Doswell et al. (1992). Initial outlooks for severe weather potential give considerable weight to the predicted evolution of large-scale features as depicted by model output and cover time periods of 24, 21, and 18 h ending at 1200 UTC. Partly due to the significant improvement in the 24–48-h predictions from numerical models run at NMC, SELS instituted a second-day convective outlook in 1986 that covered the subsequent 24-h period beyond the first-day outlook. Because these outlooks are mainly intended as guidance for planning purposes and the time periods involved are long, the forecasts will generally cover larger areas than severe weather watches. As the severe potential approaches realization, the forecaster's focus shifts to analyses and prognoses on smaller time and space scales. When the threat of severe weather becomes sufficiently evident and can be narrowed down to an area of about 64 000 km^2, a tornado or severe thunderstorm watch is issued covering a time period of about 2 to 7 h in advance.

To bridge the gap in the information flow from SELS to field offices between the issuance of the convective outlook and the watch, a new product called the mesoscale discussion was initiated in 1986. This product provides guidance on developing convective situations on a much smaller scale than the convective outlook and gives the field forecaster some indication of where watches may be required. By doing this, the coordination process is greatly facilitated. This is important since convective activity and watch decisions frequently impact more than one forecast office's area of responsibility.

1) CONVECTIVE OUTLOOKS

These products are disseminated as both text on the AFOS (Automation of Field Operations and Services) network and as a graphic. A graphic version is also transmitted once a day via DIFAX. The product shows areas of severe thunderstorm potential for the period in question as well as forecast areas of nonsevere thunderstorms. An indication of the extent of severe thunderstorm activity within an area is provided by assigning risk categories: slight, moderate, or high (see Table 1). The text version also includes a forecast discussion and the rationale for what is being forecast. The outlook provides the user with preliminary indications on the geographical focus for the "problem of the day" (Ostby 1979). The initial convective outlook is issued at 0700 UTC and covers the 24-h period from 1200 UTC to 1200 UTC the following day. The outlook is updated routinely at 1500 and 1930 UTC and amended when necessary on an unscheduled basis. A second-day outlook that covers the 24-h period beginning at 1200 UTC the following day is issued at 0800 UTC. This product includes forecast areas of severe thunderstorms but risk categories are not assigned.

TABLE 1. Definition of convective outlook risk categories.

Category	Contraction	Definition
Slight	SLGT	2% to 5% coverage or 4–10 manually digitized radar (MDR) blocks with severe thunderstorms per 260 000 km^2.
Moderate	MDT	6% to 10% coverage or 11–21 MDR blocks with severe thunderstorms per 260 000 km^2.
High	HIGH	Greater than 10% coverage or more than 21 MDR blocks with severe thunderstorms per 260 000 km^2.

2) MESOSCALE DISCUSSIONS

The mesoscale discussion has been an important addition in the SELS suite of products. As mentioned previously, it is designed to bridge the gap between the convective outlook and the subsequent issuance of watches. This product provides the field forecaster with the current thinking of SELS on developing or ongoing significant mesoscale phenomena. This includes not only thunderstorm activity that may require subsequent issuance of a tornado or severe thunderstorm watch but also short-term guidance on heavy snow or rain and even areas of fog that may be occurring on the mesoscale.

3) SEVERE WEATHER WATCHES

Watches—tornado or severe thunderstorm—are issued when the SELS forecaster believes there are indications that there is a strong potential for severe weather over a specific area. These watches, as mentioned previously, are generally for an area of about 64 000 km^2 and, while becoming valid usually within an hour after issuance, they most often apply to the time interval of about 2 to 7 h ahead. The geographical areas covered take the form of a rectangle or parallelogram. The primary purpose of the watch program is to allow the public and other concerns enough time to prepare for the possibility of severe weather development. This involves reviewing tornado safety rules, listening to NOAA weather radio or commercial TV and radio for latest information, and watching the skies for indications of threatening weather. Then, ideally, when warnings need to be issued by local weather service offices, the public is prepared to respond in the most appropriate way. Another use of the watch program is to allow emergency managers to deploy tornado spotters in their areas of jurisdiction prior to tornado development. This is an integral part of the NWS watch/warning program.

4) STATUS REPORTS

Status reports provide periodic updated information as to the severe weather situation in ongoing watches. This can include information such as recent reports of severe weather in the watch, significant convective development, or the latest thoughts by SELS as to whether the watch might be canceled, reissued, or allowed to continue to expiration. The status report may also include guidance information on where the severe weather threat has ended within the watch.

5) PUBLIC SEVERE WEATHER OUTLOOK

When NSSFC anticipates a significant and/or widespread outbreak of severe weather, it may issue a severe weather statement to the public that stresses the seriousness of the situation, defines the threat area, and provides information on the timing of the outbreak. The purpose of this product is to heighten the awareness on the part of the public and prepare concerned interests for severe weather watches that will be issued later. This issuance will always follow a convective outlook that contains a "high" risk area and occasionally a "moderate" risk that appears potentially life threatening. It is an excellent vehicle for getting the attention of external users as well as alerting NWS field offices to the "problem of the day."

c. Aviation guidance and forecasts

In November 1982, the National Aviation Weather Advisory Unit (NAWAU) became an operational entity at NSSFC, centralizing the preparation of aviation area forecasts, AIRMETs (Airman's Meteorological Advisories), and nonconvective SIGMETs. Prior to the establishment of NAWAU, these functions were divided among nine NWS forecast offices throughout the United States. The unit also incorporated the centralized Convective SIGMET (WST) Unit, which had been operating within NSSFC since 1978 (Mathews 1985).

1) CONVECTIVE SIGMET SECTION

This unit issues bulletins to aviation interests for inflight hazardous weather phenomena associated with thunderstorms for anywhere in the conterminous 48 states. Specifically, convective SIGMETs are issued for thunderstorms that are severe, embedded, or form a line. Large areas of strong, but not necessarily severe, thunderstorms also require convective SIGMETs. These hourly bulletins describe the location, intensity, movement, and expected trend of the thunderstorms for the next 2 h. Appended to each bulletin is an outlook that delineates areas that may require convective SIGMET issuances during the forthcoming 2- to 6-h time period. The outlook also includes a discussion of forecast reasoning.

2) IN-FLIGHT ADVISORY AND AREA FORECAST SECTION

Aviation advisories and forecasts for the 48 conterminous states are issued by this section. The advisories, for potentially hazardous nonconvective flying weather, are broadcast through FAA facilities to aircraft in flight. Nonconvective SIGMETs are issued for severe turbulence and icing, severe sand or dust storms, or volcanic ash plumes. AIRMETs are issued for moderate turbulence and icing, low ceilings and visibilities requiring instrument flight rules, extensive mountain obscuration, and sustained winds in excess of 30 kt. They also include information on nonconvective low-level wind shear and the freezing level.

Area forecasts are issued three times daily and are valid for periods up to 18 h. These forecasts serve as a primary pilot weather-briefing tool for FAA flight service station briefers. Each issuance contains forecasts of cloud amounts, bases and tops, restricted visibilities, and precipitation.

d. Synoptic interpretation guidance

This program involves the receipt, processing, and interpretation of satellite data provided by the Geostationary Operational Environmental Satellites (GOES). Imagery is electronically displayed for use by NSSFC forecasters and is also relayed over facsimile circuits to NWS forecast offices over the 48 conterminous states. Imagery is also relayed to a number of other government agencies as well as private and commercial organizations.

The satellite data interpretation function requires a careful analysis and interpretation of satellite data that pertains to the United States and offshore ocean areas. From this, a synoptic interpretation message (SIM) is prepared and transmitted three times daily with updates as warranted by changing conditions. The SIM includes information on the location, movement, and changes in intensity of all significant weather systems as depicted by satellite sensors and other data sources. This information is useful to forecasters throughout the United States as input to their weather forecast programs.

4. Research and development

a. General

The Techniques Development Unit (TDU) of the NSSFC is pursuing a program of organized research and development aimed at improving the forecasting ability of the NSSFC operational meteorologists. The unit's activities include scientific studies on weather conditions leading to severe storms, development and implementation of modern interactive computer technology in the forecast environment, development of diagnostic techniques and procedures for severe storm- and aviation-related forecast problems, development of techniques and procedures that will improve the efficiency and effectiveness of forecasters, evaluation of new data sources for operational utility, and verification of NSSFC forecasts, as well as verification of the NWS national watch/warning program. The unit has responsibilities for the operations of and development for a variety of NSSFC computer systems. These include two Automation of Field Operations and Services computer systems; two Data General (MV/7800 and 9300) computers used for NSSFC data collection, message composition, communications, and data processing; the Centralized Storm Information System and the VAS (Visible–infrared spin scan radiometer, atmospheric sounder) Data Utilization Center used for satellite, radar, model, and observational data ingestion and interactive processing; and a remote job entry to the NWS NAS 9050 computers used for model data access and computationally intensive tasks.

b. *Technique implementation: Improved efficiency and productivity*

The implementation of interactive computer-processing capability has had a significant positive impact on NSSFC operational programs. The first step was the installation in December 1980 of a remote terminal to the McIDAS (Man–Computer Interactive Data Access System) system at the University of Wisconsin (Suomi 1977). NSSFC forecasters were able to access satellite information and perform analyses and intercomparisons of data in real time (Doswell et al. 1982). It also provided a means for assessing the usefulness of soundings from the VISSR Atmospheric Sounder (Smith et al. 1981; Anthony and Leftwich 1984; Mosher and Schoeni 1988). In February 1982 a "stand-alone" system referred to as CSIS (Centralized Storm Information System) was installed at NSSFC. CSIS came about as a joint effort by the National Weather Service (NWS), the National Environmental Satellite Service (NESS), the National Aeronautics and Space Administration (NASA), and the University of Wisconsin's Space Science and Engineering Center (SSEC). It represented a significant advance toward the development of a handling, analyzing, intercomparison, and display system for real-time data from all available sources. It was specifically intended to demonstrate its applicability to the severe local storm forecast problem. The hardware consisted of a GOES receiving antenna system, three Harris/6 computers, three interactive terminals, an FAA "604" observational data input, two autodialers for accessing weather radar data, and an interface to the NSSFC MV computer system (Anthony et al. 1982; Mosher and Schaefer 1983).

Prior to the advent of McIDAS and CSIS, NSSFC forecasters were presented with a wide variety of information, generally on different map scales, projections, and display systems. The assimilation of this data was by and large a mental process. Furthermore, some of the data, especially satellite, was not as current as needed. The importance of accessing and manipulating real-time data as quickly as possible is paramount when dealing with mesoscale phenomena on an operational basis. CSIS brought a much-needed tool for solving these problems and a capability for forecasting severe local storms with an almost immediate payoff in terms of forecast skill (Weiss 1983; Ostby 1984; Mosher 1985).

During the ensuing years, TDU and operational meteorologists worked together to improve CSIS, implementing numerous diagnostic techniques and analyses. The "bottom-up" philosophy employed ensured a system within which the installation of new or improved software offered a solution or an improved procedure directly related to an operational need (Mosher and Schaefer 1983). A reminder of the importance of this concept was recently made by Doswell (1992) in his discussion on workstation design. The ability to access timely satellite imagery and conventional data rapidly as well as manipulate and generate various derived fields and parameters revolutionized the way operational forecasting was conducted (Anthony et al. 1982; Weiss 1983; McCann et al. 1983; Ostby 1984; Mathews 1985; Mosher 1985; Edman and Mathews 1989). The newer technology also facilitated a variety of investigations by NSSFC meteorologists. A partial list of this application includes studies on satellite imagery interpretation (McCann 1983a, 1983b; Smith and Mosher 1989), studies on heavy snow and heavy rain (Beckman 1987, 1990), helicity calculations (Leftwich 1990), and special case studies (Hales 1984; Johns and Leftwich 1988; Browning et al. 1989; July 1990).

A more powerful system, called the VAS Data Utilization Center (VDUC), was implemented at NSSFC in 1989. Using an IBM mainframe-based computer system, it has replaced many of the functions previously performed on CSIS, and has become the main interactive system supporting NSSFC operations (Browning 1991). It has also, because of its greater processing power, been able to generate fields and parameters of greater number (Browning 1992) and complexity such as wind shear/buoyant energy relationships (Johns et al. 1990), interactive skew T–log$p$ analyses (Bothwell 1992), and improved visualization techniques (Cope 1992). Also, newer datasets are being routinely ingested, such as profiler (Leftwich and Beckman 1991) and lightning networks (Lewis 1989) for operational use.

Operational application at NSSFC of interactive computer processing systems for more than ten years has brought about a dramatic rise in forecaster productivity as well as enhanced forecast performance and expanded services, while at the same time the size of the staff has been reduced. Added functions have included the consolidation and centralization of the aviation functions, the centralization of the SFSS functions for the conterminous United States, and the establishment of the "meso desk" to produce mesoscale discussions. With the consolidation of the NAWAU and SFSS functions at NSSFC, a total of 38 NWS staff positions have been eliminated while services to the public have remained the same or improved. Furthermore, the support staff has been reduced by 15 positions (Mosher 1991). One specific example of staff reduction involved the convective SIGMET program. Automating part of the process to automatically ingest MDR (manually digitized radar) data and interactively construct convective SIGMET areas allowed for the elimination of a five-member unit whose function was to manually plot such data and read off city locations serving as points bounding an area to be "sigmetted" (Edman 1988). Not only did this result in substantial resource savings, but it eliminated errors that crept in due to the rather cumbersome transposing process.

5. Severe storms forecast improvement and service value

a. Recent trends

It has been mentioned previously that the advances in interactive computer processing have been accompanied by significant improvements in forecast skill. There are a number of ways to measure the effectiveness of the severe weather forecast program. One obvious way is to compile verification statistics on tornado and severe thunderstorm watches that are issued. Details on the specifics of NSSFC verification procedures as well as a complete verification analysis are contained in a companion article by Anthony and Leftwich (1992). Figure 1 shows the number of watches issued by the SELS unit from 1973 through 1991, subdivided by type: tornado and severe thunderstorm. While the annual number of tornado watches has remained fairly steady during the period, there has been a significant increase in the number of severe thunderstorm watches issued in recent years. While this is probably due in

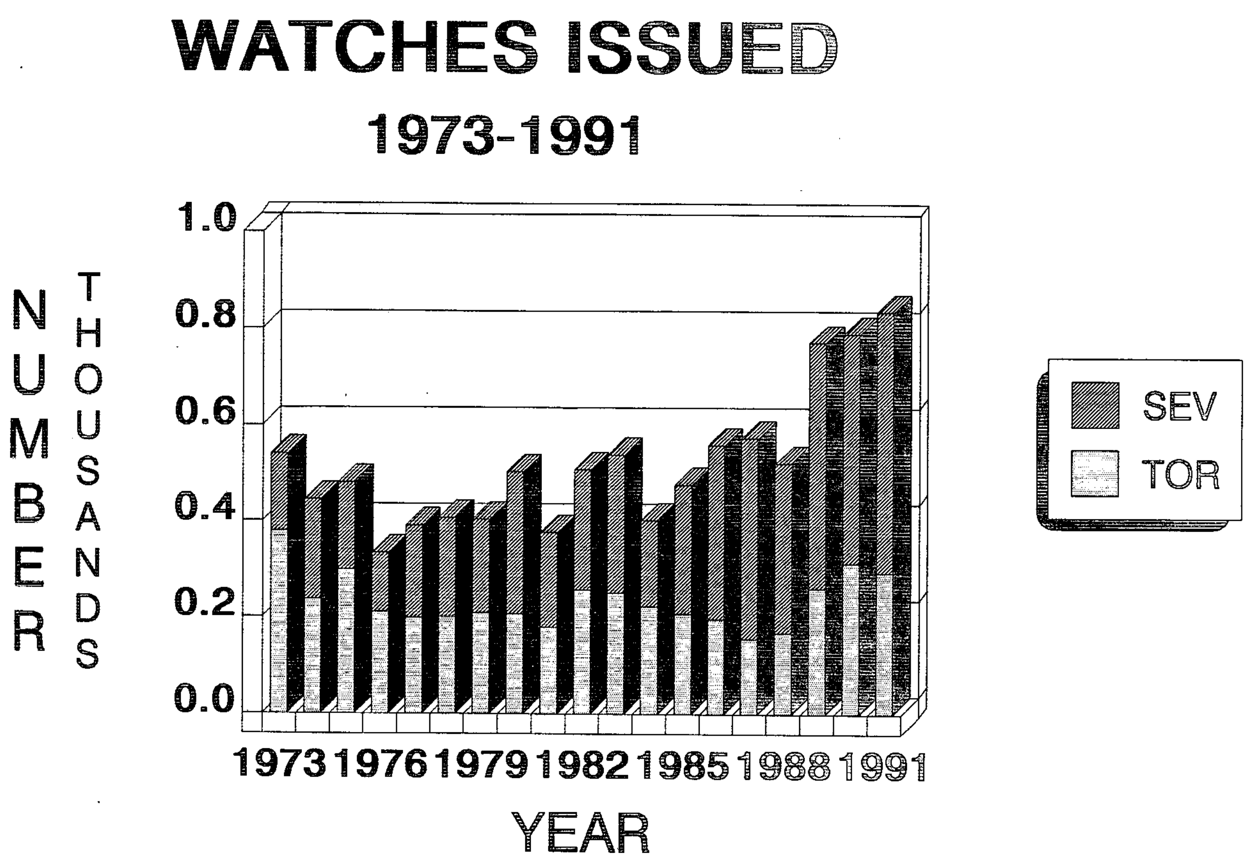

FIG. 1. Severe weather watches issued by SELS, 1973–1991. Tornado watches (TOR) represented by shading and severe thunderstorm watches (SEV) by hatching.

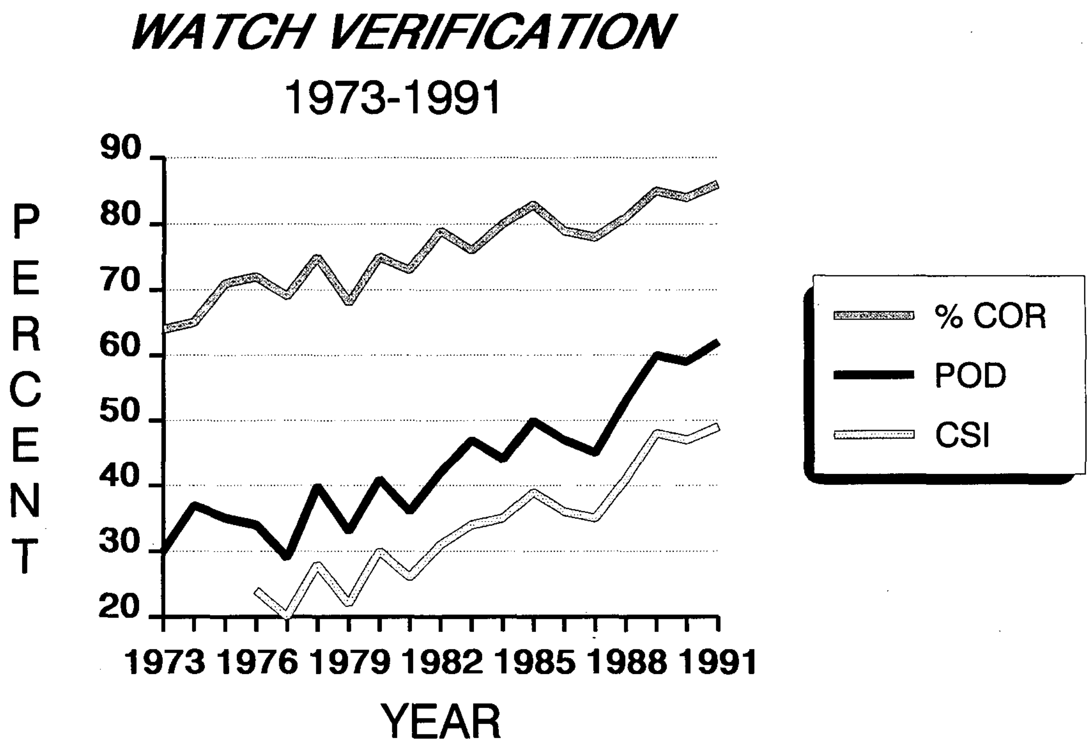

FIG. 2. Severe weather watch verification, 1973–1991. Upper curve represents percent correct (% cor); middle curve, probability of detection (POD); lower curve, critical success index (CSI).

part to the increased emphasis in reporting of severe events (Hales and Kelly 1985), there has also been an improved forecasting capability and increased confidence in being able to predict some of the nontornadic events. This has no doubt been brought about by improved forecast methods and diagnostic tools made possible by CSIS and VDUC.

One of the verification measures, percent correct, is shown in Fig. 2. For the purpose of this evaluation, a severe weather watch (tornado or severe thunderstorm) is considered to have verified if either one or more tornadoes occur during the valid time of the watch or a severe thunderstorm event (hail three-fourths of an inch or greater in diameter, surface winds of 50 knots or greater, or winds that cause damage). The source of this event database is from the publication *Storm Data.* The upper curve in Fig. 2 gives the percent correct for 1973–1991. A substantial increase with time can be seen rising from 63% in 1973 to 86% in 1991. Another effectiveness measure is the so-called probability of detection (POD). This statistic asks the question: Of the severe events that occurred, what percent occurred in valid watches? This is represented by the middle curve in Fig. 2. Note that in 1973 about 30% of severe events were captured by valid watches and that by 1991 that figure had risen to 61%. The bottom curve is the critical success index (CSI) (Donaldson et al. 1975) and exhibits the same improvement trend.

SELS performance can also be evaluated by considering the PODs for the more significant tornadoes and excluding those in the "weak" category, that is, those classified as F0 and F1 (Fujita 1973). Data compiled at NSSFC show that of the approximately 800 tornadoes that occur each year, about 650 are in the weak category. While all tornadoes represent a potential hazard to life and limb, the smaller number of stronger tornadoes, F2–F5, about 150 annually, are a greater threat, as a rule. For the period 1980–1991, of the 614 tornado-related fatalities, 570, or 93% occurred in F2–F5 tornadoes. Therefore, forecast performance in dealing with this class of tornadoes is of great importance. Figure 3 depicts this performance, showing the percent of F2–F5 tornadoes in tornado watches, severe thunderstorm watches, and the two combined. Two things from this figure stand out. First, the ability to precede F2–F5 tornadoes with watches has risen dramatically from 42% in 1978 to 87% in 1991. The second important point is that the SELS forecaster shows considerable forecasting skill in discriminating between tornado and severe thunderstorm situations. For example, in 1991, of the 147 "significant" tornadoes, 72% were in tornado watches while only 15% were in severe thunderstorm watches.

Another important consideration in evaluating forecast effectiveness is how well "violent" tornadoes (F4–F5) are forecast. During the 10-yr period 1982–

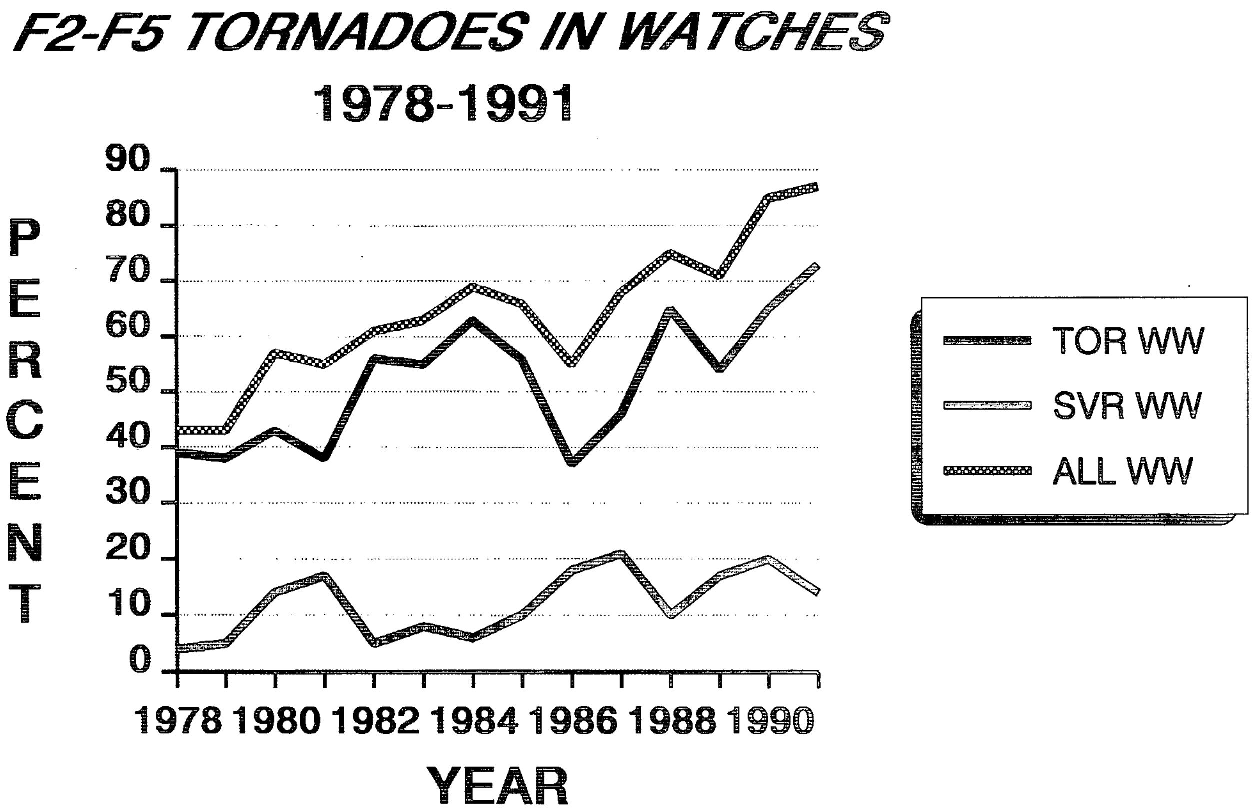

FIG. 3. Percent of F2–F5 tornadoes in severe weather watches, 1978–1991. Bottom curve shows percent in severe thunderstorm watches (SVR WW); and the middle curve, tornado watches (TOR WW). The upper curve (ALL WW) is the sum of the lower two.

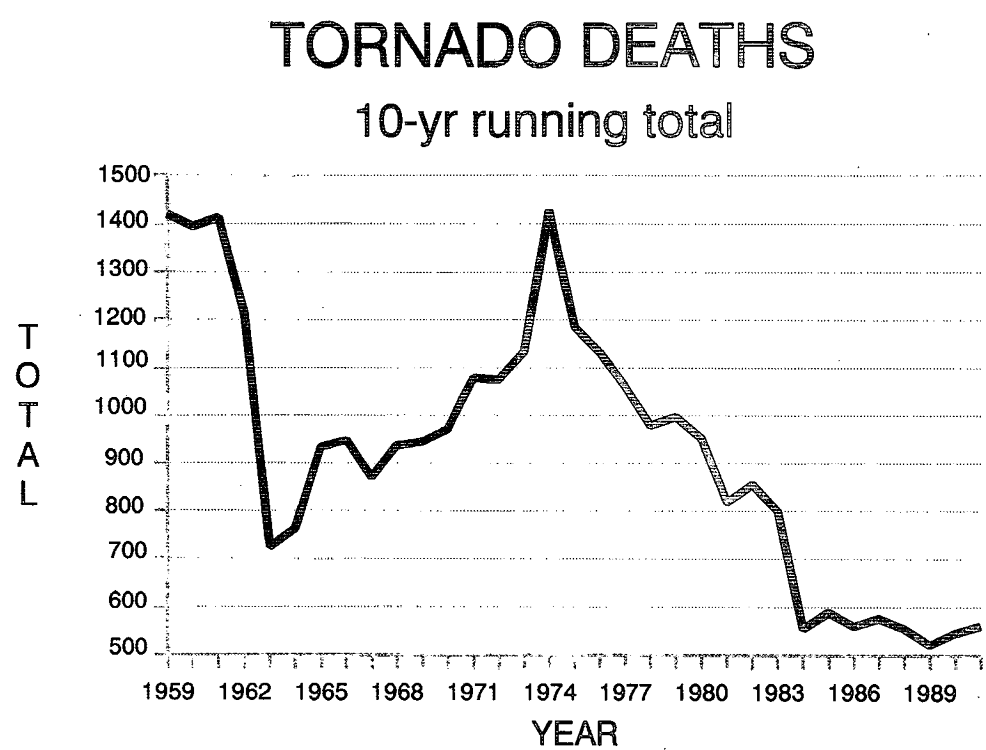

FIG. 4. Ten-year running total of U.S. tornado fatalities. Abscissa year label represents the ten-year period ending that year.

1991, there were 71 of these monster tornadoes in the United States. Of these, 66 (93%) were in severe weather watches: 60 (85%) in tornado watches, and six (8%) in severe thunderstorm watches. These 71 violent tornadoes killed 274 people. Of the 274 deaths, 270 (99%) happened in severe weather watches: 211 (77%) in tornado watches and 59 (22%) in severe thunderstorm watches.

Finally, a look at the trend of the death toll from tornadoes in the United States reveals a significant downward trend. Figure 4 gives a 10-yr running total of tornado fatalities. The large "spike" around 1974 is due to the heavy death toll produced by both the 1965 Palm Sunday outbreak and the 1974 "superoutbreak" being in the same 10-yr period. Since 1974 there has been a marked decrease such that in the 10-yr period ending in 1991, there have been only 521 deaths. This is a far cry from the 1950s, when there were over 1400 people killed by tornadoes. The reason for this success certainly involves NSSFC and SELS, but other important factors are involved as well. Significant improvements in the NWS warning program and preparedness efforts at the local weather service office, as well as safety and preparedness efforts by emergency managers, volunteer spotters, and ham radio operators, resulted in a more enlightened public and all contributed to this remarkable trend.

b. SELS performance during 15–17 June 1992

A vivid example of how much service has improved can be seen from the severe weather outbreak that occurred over the central United States during the three-day period 15–17 June 1992. Table 2 summarizes the number of severe weather events and how many were contained in severe weather watches. SELS issued 36 watches over the three-day period, with 159 of the 172 tornadoes (92%) contained in watches and 403 of the other 462 severe events (87%). Despite the heavy workload, the SELS forecasters were capable of staying on top of the situation. It was an excellent example of the improved productivity and effectiveness mentioned earlier. It is truly amazing that with 172 tornadoes occurring (an unusually high number), there was only one directly related deaths. Early findings indicate that several of the tornadoes were strong (F2–F3) or violent (F4–F5) with pathlengths in tens of miles.

TABLE 2. Tornado (tor) and severe thunderstorm (svr) events for the period 15–17 June 1992 (based on preliminary data). "All" refers to the sum of the two and "in WW" are those events in severe weather watches.

	Tor	In WW	Svr	In WW	All	In WW
15 June	61	55	58	40	119	95
16 June	66	63	158	141	224	204
17 June	45	41	246	222	291	263
Total	172	159	462	403	634	562

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ZCZC MKCSWODY2 000
ACUS2 KMKC 140744
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2ND DAY SEVERE OUTLOOK...REF AFOS NMCGPH98O

VALID 151200 - 161200Z ..GEN TSTM FCST NOT INCLUDED..

THERE IS A RISK OF SVR TSTMS TO THE RGT OF A LN FM GLD BFF
35 NW RAP 20 N Y22 ATY OTG MKC SPS 80 SSW CDS LBL GLD.

SVR WX EVENT FCST FOR DY1 EXPCD TO CONT INTO DY2 OVR CNTRL U.S.AS
STG VORT LOBE ROTATES NE ACRS CNTRL PLAINS. DEEP UPR LVL LOW MOVG
INTO NRN ROCKIES DURG PD WITH SHARP TROF EXTENDING SWD INTO AZ.
VORT LOBE PROGD TO MOVE FM ERN CO ACRS KS INTO NEB/SD AREA FIRST.
HALF OF PD AS H5 WND MAX EXCEEDING 50 KT THRUSTS NE FM NRN NM INTO
WRN KS/CNTRL NEB BY 16/00Z. POTENT DRY LN EXPCD TO MOVE EWD FM
CO/NM INTO OK/KS/NEB DURG DY2 WHILE SLY LOW LVL JET BRINGS LOW LVL
MSTR NWD ACRS CNTRL PLAINS. SFC DEW PTS IN THE MID/UPR 60S FM
CNTRL/ERN NEB S ACRS PTNS KS/OK WILL PROVIDE INGREDIENTS FOR SVR
TSTM DVLPMNT ACRS OTLK AREA. AMS PROGD TO BE VRY UNSTBL WITH SFC
BASED LI OF MINUS 6 TO MINUS 9 ACRS OTLK. ISOLD SVR TSTM ACTVY PSBL
DURG MRNG OVR WRN PTN OTLK AREA WITH SCTD SVR TSTMS LKLY DURG
AFTN/EVE AHD OF DRY LN FM SD/NEB INTO KS/OK. STG TORNADOES PSBL AS'
DIR SHEAR/INSTBY WITH BE SUFFICIENT FOR SUPERCELL DVLPMNT.

..WILSON.. 06/14/92
NNNN
```

FIG. 5. Second-day convective outlook issued at 0800 UTC 14 June 1992, valid for the 24-h period from 1200 UTC 15 June to 1200 UTC 16 June. Categories of risk are not included nor is a forecast of "nonsevere" thunderstorms. Standard meteorological contractions are used.

On 14 June, forecasters at NSSFC recognized the potential for a severe weather outbreak on 15 June and so indicated in the 0800 UTC issuance of the second-day outlook (Fig. 5). Unlike the day 1 outlook, the longer-range outlook does not attempt to assign a risk category. It can be seen from the text of the day 2 outlook that parameters were pointing toward significant severe weather, as noted by forecaster Wilson, stating that strong tornadoes were possible. As the weather situation continued to evolve, subsequent issuances carried a similar theme. The 1500 UTC day 1 outlook (Figs. 6 and 7) characterized a moderate risk and pointed out that a public severe weather outlook would follow (these outlooks are always issued when a high risk is predicted and occasionally when a moderate risk is deemed to have the potential for widespread and/or significant severe weather).

The public severe weather outlook (Fig. 8) issued at 1535 UTC on 15 June stressed the seriousness of the situation. Subsequent mesoscale discussions (Fig. 9) informed interests of the unfolding situation and provided valuable insights to current thinking. One of the first of 11 watches issued that day was tornado watch number 364[1] (Fig. 10). It used "enhanced wording," that is, it characterized the situation as "particularly dangerous with the possibility of very damaging tornadoes." Like the high-risk category and the public severe weather outlook, this type of issuance is used sparingly and reserved for situations with strong severe weather potential. The severe weather that followed was widespread within tornado watch number 364. Preliminary reports showed that it contained 34 tornadoes and 6 other severe weather events. Tornado watch number 365 (Fig. 11) was also the focus for

[1] SELS watches are numbered consecutively, beginning with "one" each calendar year.

```
ZCZC MKCSWODY1 000
ACUS1 KMKC 151515
MKC AC 151500

CONVECTIVE OUTLOOK...REF AFOS NMCGPH94O

VALID 151500 - 161200Z

THERE IS A MDT RISK OF SVR TSTMS TO THE RGT OF A LN FM DDC IML
40 NW MHN ANW OLU LNK TOP EMP P28 DDC.

THERE IS A SLGT RISK OF SVR TSTMS TO THE RGT OF A LN FM CSM
80 WSW CSM LBL 30 W GLD AKO GCC REJ Y22 AXN FRM DSM COU 60 SE TBN
SGF BVO CSM.

GEN TSTMS ARE FCST TO THE RGT OF A LN FM 50 S P07 BGS 50 NNE AMA
TAD GCN NID MER RBL PDT 50 NW FCA ...CONT...CMX MTW TOL YNG IPT
BOS.

12Z RAOBS AND STLT IMAGERY INDC MID LVL SPEED MAX (65 KT AT 500 MB)
IS NR GUP...FARTHER S THAN INDCD ON PREVIOUS PROG PACKAGES. PRIND
THIS MAX WL EJECT NEWD INTO CNTRL PLAINS TDA...ENHANCING SLY LO LVL
JET THRU CNTRL PLAINS. THIS SHD SET UP VERY FAVORABLE HODOGRAPH FOR
SUPERCELL DVLP OVR PTNS KS AND NE. CURRENTLY SFC FNT EXTNDS FM SWRN
KS ESEWD INTO NWRN AR WITH VRY UNSTBL AIR ADVCTG NWD. EXPCT THIS
FNT TO MOV TO A NWRN KS/SERN NE PTN BY LATE AFTN. DRY LN LKLY TO
MOV NEWD TO A GLD/DDC/GAG LN BY 00Z. ALL THESE FEATURES SUGGEST
THAT ISOLD SUPERCELLS WITH PSBLY STG TORNADOES MAY DVLP NR BDRYS
THRU PTNS KS AND NE AS OUTLINED IN MDT RISK AREA. A PUBLIC SEVERE
WEATHER OUTLOOK WILL BE ISSUED WITH THIS IN MIND.

OTHER SVR TSTMS MAY DVLP IN WARM ADVCTN ZONE OVR PTNS NRN PLAINS
AND ALG WRN FNTL BDRY INTO WRN MO AND WRN IA.

PUBLIC SEVERE WEATHER OUTLOOK /MKCPWOMKC/ WL BE ISSUED AT 16Z.

..JOHNS.. 06/15/92
NNNN
```

FIG. 6. Convective outlook issued at 1500 UTC 15 June 1992. Forecast is valid from that time through 1200 UTC 16 June.

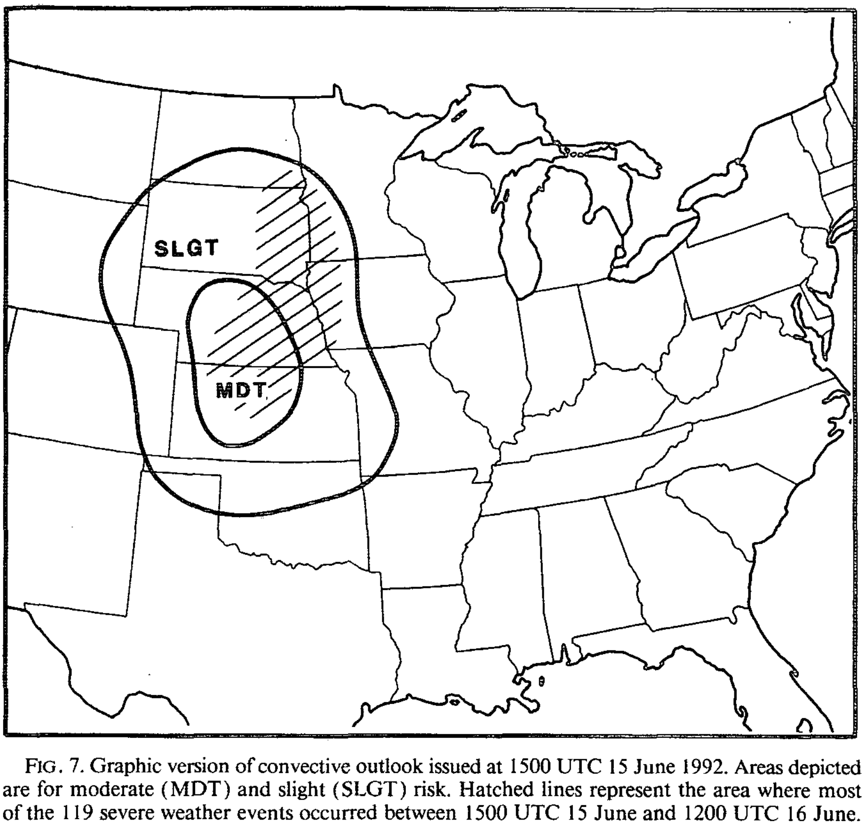

FIG. 7. Graphic version of convective outlook issued at 1500 UTC 15 June 1992. Areas depicted are for moderate (MDT) and slight (SLGT) risk. Hatched lines represent the area where most of the 119 severe weather events occurred between 1500 UTC 15 June and 1200 UTC 16 June.

```
MKCPWOMKC
WOUS36 KMKC 15135
PUBLIC SEVERE WEATHER OUTLOOK
NATIONAL WEATHER SERVICE KANSAS CITY MO
KANSAS CITY MISSOURI
1035 AM CDT MONDAY JUNE 15 1992

..SEVERE THUNDERSTORM OUTBREAK OVER PARTS OF THE CENTRAL PLAINS
TODAY AND TONIGHT..

THE NATIONAL SEVERE STORMS FORECAST CENTER IN KANSAS CITY MISSOURI
IS FORECASTING AN OUTBREAK OF SEVERE THUNDERSTORMS AND TORNADOES
TODAY AND TONIGHT OVER PARTS OF THE CENTRAL PLAINS STATES.

THE STATES WHICH ARE MOST LIKELY TO EXPERIENCE THE BRUNT OF THE
SEVERE THUNDERSTORM ACTIVITY TODAY AND TONIGHT INCLUDE..

..CENTRAL AND SOUTHEASTERN NEBRASKA..
..AND MOST OF CENTRAL AND NORTHEASTERN KANSAS..

A STRONG WEATHER SYSTEM LOCATED OVER THE WESTERN UNITED STATES IS
FORECAST TO MOVE EAST TODAY AND TONIGHT RESULTING IN A STRONG
THREAT OF SEVERE THUNDERSTORMS OVER PARTS OF THE GREAT PLAINS.
SOUTHERLY WINDS ARE EXPECTED TO INCREASE TODAY OVER THE CENTRAL
PLAINS BRINGING MOIST AND UNSTABLE AIR NORTHWARD FROM THE GULF OF
MEXICO. STRONG WINDS IN THE UPPER LEVEL JET STREAM WILL BE MOVING
NORTHEAST FROM ARIZONA AND NEW MEXICO INTO THE CENTRAL PLAINS
TODAY... AND SHOULD INTERACT WITH THE UNSTABLE AIRMASS OVER KANSAS
AND NEBRASKA BY MID AFTERNOON...CAUSING INTENSE THUNDERSTORMS TO
DEVELOP RAPIDLY.

THIS POTENT SEVERE WEATHER SITUATION WILL BE ENHANCED BY AN
INTRUSION OF WARM DRY AIR MOVING NORTHEASTWARD FROM THE SOUTHERN
HIGH PLAINS REGION. LARGE AND POWERFUL THUNDERSTORMS ARE LIKELY TO
DEVELOP WHERE THE DRY AIR ENCOUNTERS THE MOIST AND UNSTABLE AIR
OVER KANSAS AND NEBRASKA. SOME OF THE THUNDERSTORMS WILL DEVELOP
INTO SUPER CELLS WHICH WILL BE CAPABLE OF PRODUCING STRONG DAMAGING
TORNADOES IN ADDITION TO LARGE HAIL AND DAMAGING WINDS. THE SEVERE
THUNDERSTORMS ARE FORECAST TO MOVE EAST INTO PARTS OF EASTERN
NEBRASKA AND NORTHEASTERN KANSAS BY TONIGHT.

ALL PERSONS IN THE THREATENED AREA ARE URGED TO REVIEW SAFETY
RULES...AND LISTEN TO RADIO..TV..OR NOAA WEATHER RADIO FOR LATER
STATEMENTS AND POSSIBLE WATCHES OR WARNINGS. THIS IS A POTENTIALLY
DANGEROUS WEATHER SITUATION FOR THE AFFECTED AREAS AND SHOULD BE
MONITORED CLOSELY.

..BOB JOHNS..
NATIONAL SEVERE STORMS FORECAST CENTER
```

FIG. 8. Public severe weather outlook issued at 1535 UTC 15 June 1992 by SELS.

much severe activity with 12 tornadoes and 10 other severe events. One of the status reports that is routinely issued when watches are in effect is shown in Fig. 12.

The next two days saw additional outbreaks of severe weather as the same upper-air shortwave trough that triggered activity on 15 June continued its eastward progression. On the 16th, the northern and central plains were pummeled with 66 tornadoes and 158 other severe events. The convective outlook issued that morning and the location of most of the activity are shown in Fig. 13. On 17 June another major outbreak of tornadoes and severe thunderstorms occurred as the upper system moved eastward (Fig. 14). This time a vigorous squall line developed that spread rapidly across the upper Mississippi valley into the Great Lakes region. Although there were fewer tornadoes (45), 246 reports of large hail and damaging winds were received. The intense squall line brought about widespread downburst winds and represented a particular threat to aviation interests. The convective SIGMET unit in the outlook portion of its 1555 UTC issuance called attention to this by terming the situation as "very potent and potentially dangerous for aviation interests in the Great Lakes–Upper Midwest region" (Fig. 15).

```
ZCZC MKCSWOMCD ALL 151853;369,0982 402,1037 419,1021 383,0965;
ACUS3 KMKC 151853
MKC MCD 151853

SELS MESOSCALE DISCUSSION FOR ...N CNTRL KS/S NEB...
CONCERNING... SEVERE THUNDERSTORM POTENTIAL

SFC TEMPS AND DWPNTS ARE BOTH RSG RPDLY ACRS CNTRL KS... WITH 70S
DWPNTS NOW INTO N CNTRL PARTS OF THE STATE. RESULTING AMS HAS BCM
VERY UNSTBL WITH LI/S OF MINUS 9 TO MINUS 11 E OF DDC/GLD AND W OF
MHK/ICT. AXIS OF HIGHEST INSTBY IS FM GAG TO HLC/HYS. MAXIMUM LOW
LVL MSTR CNVGNC AND THETA-E ADVCTN HAVE BEEN CNTRD FM CNTRL KS TWD
HLC DURG PAST COUPLE HRS. SFC TRAJS ARE ALSO CONVERGING TWD AREA
W SLN TO N HLC. 18Z STLT IMAGERY SHOWED SHRTWV ENTERING WRN KS AND
SW NEB... WITH SOME ASSOCD MID LVL DRYG. CAP APPRS TO BE BCMG WK
ACRS N CNTRL KS INTO S AND SW NEB. COMBINATION OF LOW LVL AND UPR
LVL DYNAMICS INDC CAP IS LKLY TO BRK DURG NXT HR OR TWO... PRBLY
ALG LN NE OF RSL-MCK... WITH SVR TSTMS MOVG NEWD THEREAFTER. VSB
DATA THRU 1845Z NOT YET SHOWING SIGNS OF DVLPMT... SO WHEN
ORIENTATION OF DVLPMT BCMS MORE CLEAR CUT... WW WIBIS... LIKLY IN
NXT HR OR SO.

..JUNGBLUTH.. 06/15/92
NNNN
```

FIG. 9. Mesoscale discussion issued at 1853 UTC 15 June 1992.

```
MKCSEL4
:400,0963 381,0964 380,0994 400,0995:WWUS9 KMKC 152012
MKC WW 152012
KSZ000-160400-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 364
NATIONAL WEATHER SERVICE KANSAS CITY MO
312 PM CDT MON JUN 15 1992

.A..THE NATIONAL SEVERE STORMS FORECAST CENTER HAS ISSUED A TORNADO
WATCH FOR

     A LARGE PART OF NORTHERN AND CENTRAL KANSAS

EFFECTIVE THIS MONDAY AFTERNOON AND EVENING UNTIL 1100 PM CDT.

THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF
VERY DAMAGING TORNADOES. ALSO..LARGE HAIL...DANGEROUS LIGHTNING AND
DAMAGING THUNDERSTORM WINDS CAN BE EXPECTED.

THE TORNADO WATCH AREA IS ALONG AND 65 STATUTE MILES EITHER SIDE OF
A LINE FROM 20 MILES SOUTH OF HILL CITY KANSAS TO MANHATTAN KANSAS.

REMEMBER..A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR
TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA.
PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING
WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE
WARNINGS.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 3 1/2
IN.  EXTRM TURBC AND SFC WND GUSTS TO 70 KNOTS.  A FEW CBS WITH MAX
TOPS TO 600.  MEAN WIND VECTOR 23030.

D... TCU DVLPG 40 SSE HLC APRS TO HAVE PASSED THE POINT OF DVLPMT
INTO TSTMS..BREAKING THE CAP.  EXPCD RAPIDLY DVLPMT INTO SVR TSTM
WITH ADDTL CELLS LKLY TO DVLP.  INSTBY AND VERT SHR SUGGEST SUPER
CELLS WILL DVLP WITH STG TORNADOES PSBL.

E...OTR TSTMS.. CONT WW NR 362 AND 363.  TCU ARE DVLPG ALG DRY LN
FM NE TX INTO AREA S OF DDC.  IF CAP IS BROKEN...WW MAY BE RQRD
FARTHER S ALG DRY LN.

...JOHNS
```

FIG. 10. Tornado watch number 364 issued at 2012 UTC 15 June 1992. Note the "enhanced" wording: THIS IS A PARTICULARLY DANGEROUS SITUATION. . . .

As in the case of dealing with the severe weather of the 15th, SELS issued a suite of timely and accurate products for 16 and 17 June (not shown). Second-day outlooks, public severe weather outlooks, watches, and the various mesoscale weather monitoring products, including a heavy volume of telephone coordination calls to field offices, characterized the execution of SELS duties on both days.

An important point worthy of mention is that in order for the severe weather program to be effective, there is a need for consistent and coordinated products, especially when dealing with widespread severe weather activity. Thus, there is special emphasis made by SELS to issue a succession of watches that makes sense meteorologically and minimizes confusion. It is especially critical to have a coordinated effort when large geographical regions covering several NWS field offices' areas of responsibility are affected. Figure 16 shows the watches that were issued on 17 June over a 12-h period. Great pains must be taken in such situations to ensure that when multiple watches are issued, they are well orchestrated and do not conflict with one another; otherwise, much confusion can result and the effort compromised, leaving the severe weather program far short of its goal of protecting the public and other interests from the ravages of severe storms.

6. Future plans

NSSFC is very much involved in the National Weather Service's modernization and restructuring plans. The establishment of weather forecast offices (WFOs) that will be geographically defined and bounded by county warning areas will necessitate a different watch definition. Instead of watches outlined by rectangles and parallelograms, which suited a field structure that was by and large geographically configured by state boundaries, watches will also be configured by counties.

The new watch design using counties will allow for a more precise description of the potentially affected area and facilitate interoffice coordination. A prelim-

```
AWW KNKA 152154
MKC AWW 152153
WW 365 TORNADO NE 152230Z - 160400Z
AXIS..60 STATUTE MILES EAST AND WEST OF LINE..
75NW OFK/NORFOLK NE/ - 55WSW BIE/BEATRICE NE/
..AVIATION COORDS.. 50NM E/W /19NNE ONL - 65SSE GRI/
HAIL SURFACE AND ALOFT ..3 1/2 INCHES.  WIND GUSTS..70 KNOTS.
MAX TOPS TO 620.  MEAN WIND VECTOR 22025.
NNNN


WWUS KNKA 152157
MKC WW 152158
NEZ000-160400-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 365
NATIONAL WEATHER SERVICE KANSAS CITY MO
458 PM CDT JUNE 15 1992

.A..THE NATIONAL SEVERE STORMS FORECAST CENTER HAS ISSUED A TORNADO
WATCH FOR

     MUCH OF CENTRAL AND EASTERN NEBRASKA

EFFECTIVE THIS MONDAY AFTERNOON AND EVENING UNTIL 1100 PM CDT.

THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF
VERY DAMAGING TORNADOES.  ALSO..LARGE HAIL...DANGEROUS LIGHTNING
AND DAMAGING THUNDERSTORM WINDS CAN BE EXPECTED.

THE TORNADO WATCH AREA IS ALONG AND 60 STATUTE MILES EAST AND WEST
OF A LINE FROM 75 MILES NORTHWEST OF NORFOLK NEBRASKA TO 55 MILES
WEST SOUTHWEST OF BEATRICE NEBRASKA.

REMEMBER..A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR
TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA.
PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING
WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE
WARNINGS.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 3 1/2
IN.  EXTRM TURBC AND SFC WND GUSTS TO 70 KNOTS.  A FEW CBS WITH MAX
TOPS TO 620.  MEAN WIND VECTOR 22025.

D...EXPLOSIVE DVLPMNT OF SUPER CELLS AND TORNADOES N CNTRL KS IN
RESPONSE TO FVRBL SHEAR AND XTRMLY UNSTABLE AMS.  STMS WILL CONT TO
MV/DVLP NEWD INTO ERN NEB WITH SUPER CELLS AND TORNADOES LIKELY.

E...OTR TSTMS... CONT WW 362-364.

...HALES
NNNN
```

FIG. 11. Tornado watch number 365 issued at 2157 UTC 15 June 1992.

```
ZCZC MKCWWAMKC ALL 160529;400,0963 381,0964 380,0994 400,0995;
WWUS8 KMKC 160248
MKC WW-A 160248

STATUS REPORT ON WW NR 364

LRG CLUSTER OF SVR TSTMS CONTS TO AFFECT N CNTRL KS.  CLUSTER HAS
BEEN CENTERED JUST W OF CNK OVR MITCHELL CNTY.  DURG THE PAST HR
THERE HAS BEEN RDVLPMT OF INTS TSTMS ON SW EDGE OF THIS CLUSTER OVR
SRN OSBORNE CNTY.  THIS DVLPMT IS OCRG NR A STG SFC MSTR CNVGNC
CNTR.  DURG THE PAST HR TSTMS HV BEEN INCRG OVR SERN RICE CNTY ABT
15NW HUT.  THESE TSTMS WILL BE MOVG INTO MCPHERSON CNTY SHORTLY.
S WINDS CONT TO GUST ACRS CNTRL KS.  PROFILER WINDS INDC THE DVLPMT
OF THE LOW LVL JET ACRS CNTRL OK AND KS WITH WIND SPEEDS ARND 40
KT.  IR STLT DATA SHOW WELL DEFINED DRY LINE FM 30E HLC TO NR HYS
AND DDC AND NORTH WSHFT LN MOVG SEWD 20 KT ACRS W KS TO NR HLC.
PRESENT INDICATIONS ARE THAT WW WILL LIKELY BE REISSUED FOR PTNS OF
N CNTRL KS.  CONT WW TIL EXPIRATION AT 04Z.

..BECKMAN.. 06/16/92
NNNN
```

FIG. 12. Status report issued at 0248 UTC 16 June 1992.

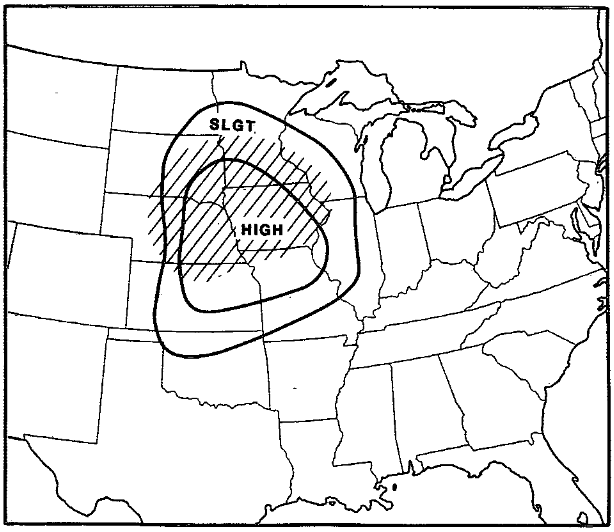

FIG. 13. Graphic version of convective outlook issued at 1500 UTC 16 June 1992 valid from 1500 until 1200 UTC 17 June. Areas are for high (HIGH) and slight (SLGT) risk. Hatched lines represent the area where most of the 224 severe weather events occurred during the period.

inary internal message will be sent to the affected NWS offices for review and coordination. The text will include a list of counties to be included in the proposed watch that the affected offices can modify as necessary and return to NSSFC, which will then release the coordinated watch to the public. This process implies that there will be longer lead times in the watches of the future. The internal coordination will be aided and streamlined by appropriately developed software to make the process take place in an efficient manner.

Convective outlooks that are issued more frequently and for shorter discrete time periods that conform better to user requirements will also be developed. In addition, outlooks for "general thunder" (nonsevere) will have isolines of probability that can be used as input for the preparation of public forecast products and other service programs.

While major improvements in severe storm forecasting have been noted and discussed, additional improvement of a substantial nature in the watch program, represented by significantly longer lead times, shorter duration watches, and smaller watch areas, with higher skill scores, will not be possible until a truly mesoscale numerical prediction model can be made operational. Until then, specifying the timing and location of supercells, squall lines, and other mesoscale convective systems hours in advance will be a formidable task. Some hope in that direction is offered by the new WSR-88Ds now being installed at NWS offices around the nation as part of the NEXRAD program.

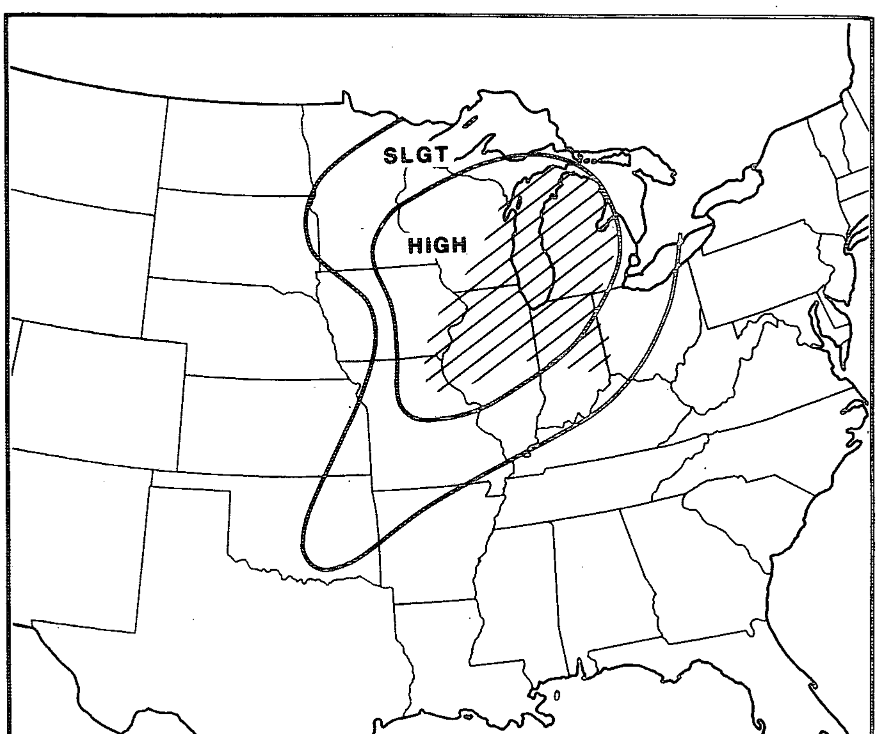

FIG. 14. Graphic version of convective outlook issued at 0700 UTC 17 June 1992 valid for period 1200 UTC 17 June to 1200 UTC 18 June. Risk areas are indicated as high (HIGH) and slight (SLGT). Hatched lines represent area where most of the 291 severe events occurred during the period.

```
MKCWSTC
WSUS41 KMKC 171555
MKCC WST 171555
CONVECTIVE SIGMET 23C
VALID UNTIL 1755Z
WI MI LM
50NE GRB
ISOLD SVR TSTM D25 MOVG FROM 2255.  TOPS ABV 450.
HAIL TO 2 IN...WIND GUSTS TO 70 KT PSBL.

CONVECTIVE SIGMET 24C
VALID UNTIL 1755Z
LM WI IL
FROM 15NE MKE-30E BDF
RPDLY DVLPG LINE TSTMS 15 MI WIDE MOVG FROM 2525.  TOPS TO 400.
TORNADOES...HAIL TO 3 IN...WIND GUSTS TO 70 KT PSBL.

CONVECTIVE SIGMET 25C
VALID UNTIL 1755Z
WI IA MO
FROM 50NNW RHI-20E DBQ-20SSW IRK
RPDLY LINE TSTMS 15 MI WIDE MOVG FROM 2525.  TOPS TO 450.
TORNADOES...HAIL TO 3 IN...WIND GUSTS TO 75 KT PSBL.

OUTLOOK VALID 171755-172155
FROM YQT-SSM-FWA-VIH-IRK-DLH-YQT
REF WW 386 AND 387.
VSBL STLT IMGRY AND ANIMATED RADAR DATA SHOWS RPD CNVTV DVLPMT OCRG
IN TWO LINES.  ONE LINE DVLPG OVER XTRM SE WI/NERN IL...THE SCND
AND PSBLY STGR LINE DVLPG FM N CNTRL WI SWD THRU ERN IA INTO NRN
MO.  AMS OVER GRTLKS RGN IS ALRDY VERY UNSTABLE WITH LIFTED INDEX
VALUES FROM -5 TO -11.  WATVAP STLT IMGRY SHOWS STG DRY PUNCH INTO
THIS AREA WITH COLD ADVCTN ALF OVER MN/IA/NW MO.  TSTMS XPCD TO
INTSFY RPDLY AND MAY REACH SVR LVLS DURG THE NEXT 1/2 HRS.  STG
WIND FIELD AND XTRM INSTBY SUG PTNTL FOR TORNADO DVLPMT IN ADDN TO
LRG HAIL AND DMGG WINDS.  THIS DVLPG WX SITUATION VERY POTENT AND
PTNTLY DANGEROUS FOR AVIATION INTERESTS IN THE GRTLKS-UPR MID WEST
RGN.

KLOTH
```

FIG. 15. Convective SIGMET issued at 1555 UTC 17 June 1992. Note the reference to the VERY POTENT AND POTENTIALLY DANGEROUS SITUATION FOR AVIATION INTERESTS. . . .

When operated in the clear-air mode, features can at times be discerned that offer clues to subsequent convective development (e.g., convergence zones) that will assist in the placement of severe weather watches. Many times, however, it is necessary to make watch decisions well before any convection or other indicators can be picked up by the WSR-88D. On the other hand, in the case of ongoing convective activity, the 88D will be of assistance for the updating and/or reissuance of watches. Obviously, the greatest benefit from the use of the new radar system will be to the WFOs in their severe weather warning program to handle ongoing or developing convective storms.

The next generation of geostationary satellites, GOES-NEXT (Shenk et al. 1987), will be of great value to NSSFC both from the standpoint of greater IR resolution and the ability to produce soundings and images at the same time (Hayden and Schmit 1991).

Advanced weather interactive processing system (AWIPS) will be an important tool in the modernized Weather Service (AWIPS-90 1985). The interactive computing capability at NSSFC will have to be compatible with AWIPS in order to communicate and coordinate with NWS field offices as well as transmit results in real time from applications programs run at NSSFC.

7. Concluding remarks

From those initial attempts some 40 years ago by a small group of dedicated meteorologists eager to answer the question "Can tornadoes be forecast?" has risen a formidable organization possessing substantial skill in tornado forecasting: an organization that has grown in stature while increasing its areas of responsibility. The National Severe Storms Forecast Center now plays a key role in severe weather prediction, forecasts of aviation hazards, national verification programs, data quality control and analysis, communications, and technology transfer.

While verification statistics on SELS performance is impressive, the "bottom line" is in terms of saving lives, and the tornado death toll that now averages around half of what it was ten years ago speaks very favorably of the system. As mentioned earlier, credit for this record extends beyond NSSFC and the NWS field offices to emergency managers, the media, community involvement, volunteer spotters, and concerned citizens.

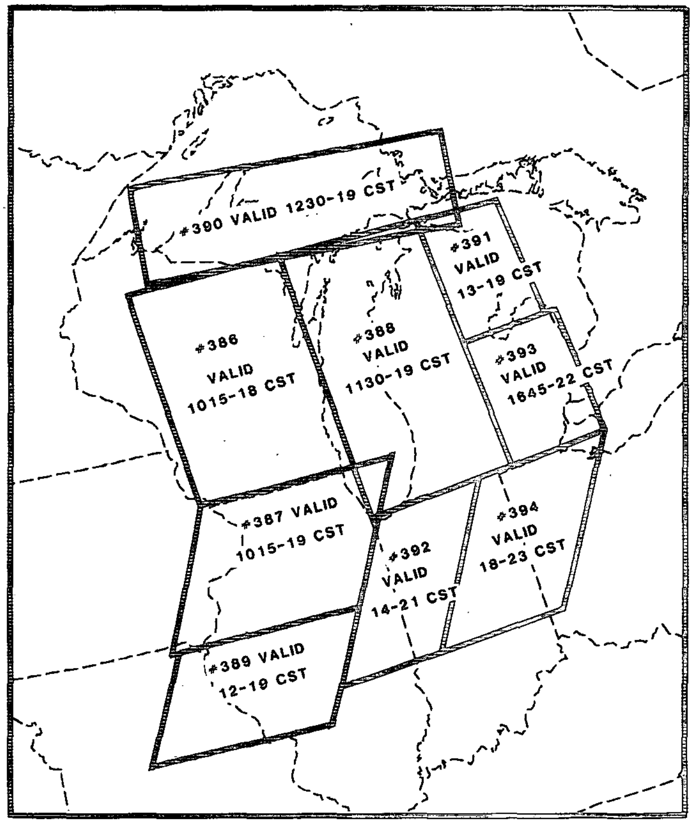

FIG. 16. Tornado watches issued by SELS 17 June 1992. Valid time of each watch is in Central Standard Time (CST).

Public response to these efforts is a key ingredient in reducing the death toll from tornadoes. The opportunity to elicit the proper response happens when there is a continuous progression of consistent weather information flowing to the public (outlook, watch, warning) that increasingly heightens the awareness of the severe weather threat and reinforces earlier guidance (Mileti and Sorensen 1990). A warning without any preceding confirming information will, in general, not be as effective as one that has been a logical follow-on to earlier sensitizing information.

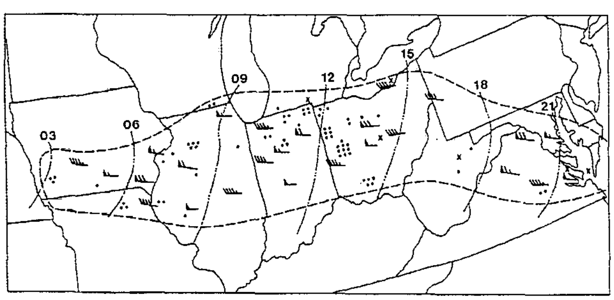

FIG. 17. Area affected by convective windstorm of 5 July 1980 (dashed line). Three-hourly squall-line positions are indicated in UTC (from 0300 5 July to 2100 5 July). Officially measured convective gusts are indicated by wind barbs [full barb signifies 5 m s^{-1} (10 kt), flag signifies 25 m s^{-1} (50 kt)]. Personal injuries (67) are indicated by dots, and deaths (6) are shown by an "x" (after Johns and Hirt 1987).

Finally, it is important in situations requiring a sequence of watches and supporting statements to be issued that they are well planned, coordinated, and nonconflicting to avoid confusion. This is especially so in those cases involving large-scale, rapidly moving convective systems, such as the one on 17 June 1992. Another example of this challenging problem for the severe storm forecaster was the classic widespread convectively induced windstorm (derecho) on 5 July 1980 described by Johns and Hirt (1987). This system began in western Iowa and spread death, injury, and destruction all the way to the East Coast, covering some 960 n mi in a matter of 18 h (Fig. 17). Such events that affect the domain of several weather service offices require a great deal of foresight and skill in issuing watches in a timely and coordinated pattern in advance of the oncoming activity.

Acknowledgments. The author is grateful to the staff of NSSFC for their high level of professionalism and skill that has brought about the many achievements in operational mesoscale forecasting over the years. During the process, this group has often found itself undergoing the growing pains of adopting advancing technology that is not always easy to accept or accommodate. To the forecasters' credit, these changes have not been simply tolerated but have been welcomed and exploited to the fullest in improving the end product, operational forecasts. The performance improvements in the severe weather watch program have been made possible by an exceptional cadre of SELS lead forecasters: Richard Anthony, John Hales, Robert Johns, Steven Weiss, and Larry Wilson.

The positive operational benefits of interactive computer processing have been made possible by Dr. Frederick Mosher, chief of the Techniques Development Unit, and his staff of expert meteorologists and computer programmers. A number of individuals contributed significantly in numerous interactions in the early days that led up to the installation of CSIS at NSSFC. Notable among these were James Dodge, James Giraytys, Michael Hunt, Allan Pearson, Joseph Schaefer, Shelby Tilford, J. T. Young, and Frederick Zbar. Thanks also go to the senior management of NSSFC for innovative ideas and strong leadership during various stages of significant programmatic changes: James Henderson, deputy director; Melvin Mathews, supervisor of NAWAU; Terry Schoeni, supervisor of the Meso/SIM section, William Pettyplace, electronics program manager, and Edward Ferguson, previous NSSFC deputy director.

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