THE JULY 13, 2004 PARSONS TORNADO EVENT: THE CONTRIBUTION OF EVOLVING PARADIGMS AND HUMAN FACTORS IN THE WARNING PROCESS

Llyle J. Barker III*
Christopher J. Miller
NWS Weather Forecast Office
Lincoln, Illinois

Elizabeth M. Quoetone
NWS Warning Decision Training Branch
Norman, Oklahoma

1. INTRODUCTION

The process of protecting life and property, the primary mission of National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS, 1999b), involves several important phases. These range from scientific analysis and identification of the threat, communication of that threat, and the action undertaken by those threatened. If any of these stages breakdown, the mission may fail.

On 13 July 2004, an F-4 tornado ripped through the Parson's Manufacturing Plant in rural Woodford County, Illinois. Although the plant was destroyed, no injuries occurred among the 150 employees who sought safety in the plant storm shelters during the event.

The scientific aspects of the 13 July 2004, Parson's Tornado Event have been the focus of several studies to date (Shimon et al, 2005; Merzlock, 2005). However, just as important to the entire severe weather warning process were the procedures in place and decisions that were made at the time. This paper will briefly focus on the major changes that have occurred in the warning process within NOAA's National Weather Service (NWS) over the past decade including the evolution from a primarily reactive process to a more proactive approach. These changes along with other human factors in the decision process will be explored in relation to the Parson's Tornado Event and the overall severe weather episode of 13 July 2004 in central and southeast Illinois.

* Corresponding Author's Address: National Weather Service, 1362 State Route 10, Lincoln, IL 62656; e-mail: Llyle.Barker@noaa.gov

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2. OVERVIEW OF CENTRAL AND SOUTHEAST ILLINOIS NWS MODERNIZATION (1995-2005)

A new commitment to improving service was implemented within the NWS during the early and middle 1990s know as the Modernization and Associated Restructuring (MAR) program (Friday, 1994). Although Simmons and Suttor (2005) suggested that changes in tornado warning casualty figures were primarily precipitated by the deployment of the WSR-88D, many changes occurred within both technology and human resource management during this same period which likely contributed to the improvements noted. These changes are interdependent and it is difficult to highlight one component over another for the reason behind the increases in service.

2.1 Technology

2.1.1 WSR-88D

The past decade has seen tremendous advances in technology within the NWS. Although, only one change among many, much of the advances were precipitated by the introduction of the WSR-88D radars most of which were deployed nationally between 1990 and 1996. Crum and Alberty (1993) outlined datasets available and the architecture of the WSR-88D. The WSR-88D at Lincoln, IL (KILX) was accepted in November 1995. In addition, another NWS Doppler-capable radar was installed in Evansville, IN (KVWX) in April 2002 and serves as an integral part of the warning system for southeast Illinois.

Previous to the WSR-88D's introduction, a WSR-74C radar (Fig. 1) at Springfield IL, and the WSR-57 radars at Evansville IN and Marseilles IL acted as the primary severe weather warning tools. These radars were operated by a single individual within a darkened room in front of a glowing phosphorus screen.

Figure 1 - WSR-74C 5 cm Radar in use at WSO Springfield IL prior to 1995. (Picture Courtesy NOAA/NWS North Webster IN.)

The deployment of the WSR-88D and its associated signal processing, algorithms, and display systems allowed the warning meteorologist to work without being isolated from the remainder of the warning team thereby enabling the integration of real-time reports and input more easily in the warning process. Obviously the ability to infer returned radar-relative Doppler velocities also made a tremendous difference in the ability of the staff to identify tornadic pre-storm environments. The ever-evolving suite of algorithm outputs, such as the Mesocyclone Detection Algorithm (Stumpf et al., 1998), Tornado Detection Algorithm (Mitchell et al., 1995), Vertically Integrated Liquid, and Precipitation Estimation (Crum and Alberty, 1993) were also important tools.

Figure 2 - WSR-88D Principal User Processor workstation in use at WFO Lincoln IL from 1995 to 2002. (Picture Courtesy NOAA/NWS Milwaukee WI.)

2.1.2 AWIPS

The Advanced Weather Interactive Processing System (AWIPS) (Fig. 3) was introduced into the NWS beginning in 2001, with prototype systems deployed as early as 1995. AWIPS integrates the ingest and display of a vast array of datasets onto one platform (MacDonald and Wakefield, 1996). This advance contributes greatly to the overall integration of data into the process of identifying a pertinent conceptual model and thereby adding a predictive component to the warning process.

Although, much of the data displayable on AWIPS was previously available to meteorologists within the NWS office, it was only viewable on separate platforms: the WSR-88D radar output was viewable only at the Principal User Processor (Fig. 2; Crum and Alberty, 1993), satellite data was only available on the Satellite Weather Information System display (Sikorski and Young, 1986), and predictive model data was only viewable on the Automation of Field Operations and Services (AFOS) system. With the introduction of AWIPS, warning teams could now use multiple workstations to overlay these and other datasets, leading to improved visualization of the science of severe weather identification and prediction. In addition, the ability to display the datasets on multiple workstations lead to collaboration and more reasonable workload division. Teams of meteorologists could divide up the decision-making tasks by geographical sectors, much like is done in air traffic control, or by anticipated threat, allowing a more focused approach to the warning process.

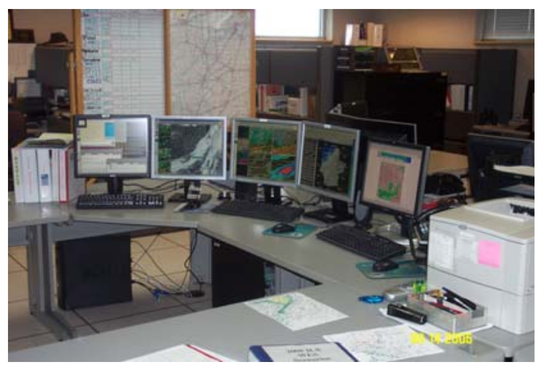

Figure 3 - Advanced Weather Interactive Processing System workstation used to integrate multiple meteorological datasets at WFO Lincoln IL since 1998.

In addition, AWIPS provides a tool to more quickly disseminate products in the event that a warning might be required. Prior to the Warning Generation (WarnGen) tool, meteorologists used PC-based software to create the text warning for dissemination to partners and customers. Although, much more efficient than earlier versions of software used on AFOS, this PC-software still required substantial manual input and editing on a separate platform. This process could sometimes require up to five minutes between the time of the decision to issue a warning and the dissemination of the product. With the introduction of WarnGen, meteorologists could now choose a storm or line of storms directly on the display of WSR-88D data, verify the motion and projected path, quickly select a series of formats from a template, and issue the product. In most situations, this process takes less than 75 seconds from the warning decision to product dissemination. Also, with the use of a graphical interface, users can identify the exact region that will likely be impacted by the hazardous weather. They are no longer tied to arbitrary political boundaries. That information is now contained as a series of latitude/longitude pairs for each vertex of the warning polygon (Waters et al., 2005). Customers may use that information to further identify those at risk.

2.1.3 Improved Modeling

Increases in computer capabilities and research efforts by university- and government-funded laboratories have lead to improved modeling of synoptic, meso-scale, and storm-scale features which have large impacts on the warning process. The Environmental Modeling Center of the National Center of Environmental Prediction has steadily upgraded its modeling capability. The Rapid Update Cycle, Weather Research and Forecasting model at resolutions as low as 4.5 km, and the Global Forecast System output to 384 hours run 4 times a day, are just a few of the tools now available to forecasters planning staffing and attempting to give advanced notice to partners and customers (NWS, 2005). Hazardous Weather Outlooks are issued routinely by offices highlighting potential dangerous weather as much as seven days in advance.

Other technologies that have impacted the warning process include the twenty-four hour availability of observations through the Advanced Surface Observing System. Other improvements include the increased spatial and temporal resolution of geosynchronous satellite data, availability of data sources on the Internet, and the introduction of automated dissemination of products through the Voice Improvement Processor on the NOAA Weather Radio All-Hazards.

2.2 Organizational Changes

Although the upgrades in technology were significant during this period, the infrastructure and resource management also underwent tremendous changes (Friday, 1984) which likely contributed significantly to the documented improvement in the warning process.

2.2.1 Weather Forecast offices

Operations at the Weather Service Offices (WSO) at Peoria and Springfield were integrated into a Weather Forecast Office (WFO) located in Lincoln in 1996. When fully staffed, these earlier offices employed nine warning staff and one support staff respectively. However, currently the Lincoln office has 17 staff members available to contribute to the warning process. This increased staffing level, combined with the new technology available, allow the warning environment to evolve beyond many of the limitations of the smaller WSOs providing greatly enhanced flexibility.

Previous to 1995, one Weather Service Forecast Office (WSFO) per state (larger states had several WSFOs) was responsible for forecasts for an entire state, while the smaller local WSOs issued hazardous weather products, took weather observations, and performed local customer service. In Illinois the WSFO at O'Hare International Airport in Chicago performed that function for the entire state. With the development of the WFO, all forecast and warning responsibility was now delegated to each individual office (Fig. 4). That structure provided much greater continuity in the overall long-term expectations of an upcoming severe weather event. From a week or more in advance, office staff can issue products and note changes in model solutions and environments that may ultimately prove important once the event arrives.

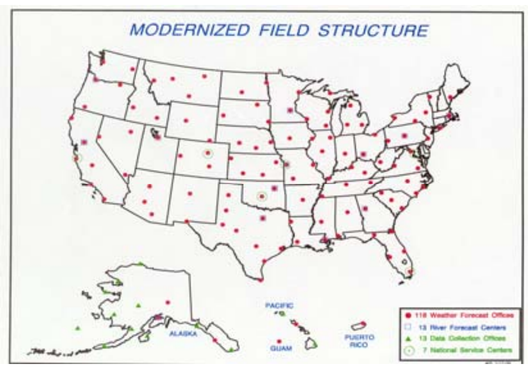

Figure 4 - NOAA's National Weather Service Weather Forecast Office field structure following the Modernization and Restructuring program. (Friday, 1994)

2.2.2 Warning Coordination Program

One additional staff member added to the compliment of the WFO is the Warning Coordination Meteorologist (WCM). The WCM acts as the primary liaison between the office and those outside the organization (NWS, 2003). Although, the WCM does occasionally work operationally, the bulk of his or her time is spent interacting with NWS partners and customers. The increased levels of support to local emergency managers allows a major focus on training weather spotters. This leads to an increase in the number and quality of ground truth reports received by the office in real-time and for post-event review purposes. Although, technology has changed significantly, the importance of the spotter has only increased following modernization as additional confirmation of ongoing weather is necessary to assess the many potentially hazardous radar signatures often evident on the WSR-88D. The number of spotters in central and southeast Illinois has grown from approximately 2100 in 1995 to over 3900 today.

In addition to the training of spotter networks, another large role of the WCM is enhancing the hazardous weather knowledge of partners, customers, and the public. Through education and preparedness campaigns, the WCM enhances understanding of the actions necessary to avoid significant impact of a hazardous weather event.

The WCM also heads the team involved in follow-up activities after a severe weather event. This is a critical function which helps discover lessons learned and then apply them in subsequent events.

2.3 Science and Operations Program

Another position that was established at each WFO during the MAR is the Science and Operations Officer (SOO). This individual is primarily tasked with ensuring that rapid advances in technology and research are infused into the WFO's operations (NWS, 1999a). With the changes in technology over the past decade and the frequent upgrading of these systems, meteorologists need to be continually exposed to locally, regionally, and nationally-prepared training and research resources. The SOO is responsible for locally facilitating and managing these programs.

The Weather Event Simulator (WES) (Magsig and Page, 2001) is one tool used by the SOO to enhance office performance. The introduction of the WES in 2001 has proven a significant contribution to the training program.

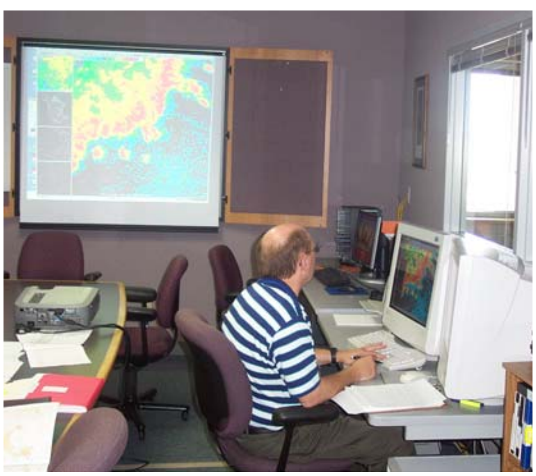

Figure 5 - A WFO Lincoln IL Forecaster using the WES.

The WES is designed to function as an AWIPS workstation ingesting archived data. The data can be past events at the local office or historical events elsewhere in the NWS that might provide trainees insight into a particular forecast or warning issue. This "train-as-you-fight" concept allows for the substantial enhancement of office expertise in a "safe" environment where feedback can be provided. This approach is similar to those used in the training of aircraft pilots and military personnel.

The goal of enhanced technological and research infusion has also enabled the NWS to participate as a partner with the research community during major field projects such as STEPS 2000 (Lang et al., 2004) and BAMEX (Davis et al., 2004). Both of these field experiments included personnel currently at WFO Lincoln. This collaboration improves the project by providing an operational perspective and experienced forecaster support, while the NWS benefits from exposure to the principal investigators in the atmospheric research community and their relevant findings.

As the integration of a larger team into the warning process becomes necessary, training on new technology and proven research needs to be supplemented with an additional focus on team building, threat communication, situation awareness (Endsley, 1988), and the overall warning process. This added dimension which was minimally addressed in NWS training programs prior to the MAR is also likely adding to the increased service levels.

2.4 Warning Decision Training Branch

Prior to the national implementation of the WSR-88D, the NWS realized that a tremendous training effort would need to be undertaken to familiarize warning-decision personnel with the vast increase in information that would be available to them. The establishment of the Warning Decision Training Branch (WDTB) in Norman OK was the result. Over 2500 meteorologists traveled to Norman to take the four-week WSR-88D Operations Course.
The course not only focused on the "knobology" of working the display processor, it also focused on the algorithms and the science behind them, as well as, the conceptual models that would require familiarization in order to effectively use the new technology.

As the number of NWS meteorologists that still needed the WSR-88D course materials diminished, the course evolved into the Distance Learning Operations Course and remains a requirement for newly hired meteorologists within the NWS.

As the residence operations course evolved, the WDTB extended their focus on improving the overall warning process within WFOs delivering a series of four Warning Decision Making (WDM) workshops from 1997 through 2003. These workshops were not only designed to reinforce the materials presented in the WSR-88D Operations Course, but to move into the implications of the changes in the warning process that were necessary to improve our services (WDTB, 2002). Although a limited number of participants from each office were able to attend these workshops, much of the material presented became cornerstones of the local office warning programs. To further expose NWS staff to the concepts, a distance-learning version of these materials was developed into the Advanced Warning Operations Course that was administered by the WDTB to the vast majority of NWS meteorologists (and all at WFO Lincoln) during the 2005 fiscal year.

2.5 Resultant Changes in Warning Operations

Vast changes in the NWS warning program for central and southeast Illinois have been evident in the technological, restructuring, outreach, and training enhancements that occurred over the past decade. Warning decision makers can now function as a component in a warning-decision team that can include multiple sectors, increased real-time feedback from spotters, enhanced communication with partners and customers, and a flexible, more uniform, division of workload. They operate in a technological environment in which they have become familiar through simulations on the WES and materials presented by the WDTB. They make use of the latest research into severe weather identification and prediction and apply the most up-to-date proven conceptual models obtained through collaboration with the research community. In addition, they bring to bear their increased understanding of the warning process, threat communication, and team motivation learned through the WDTB and other local and regional training.
At WFO Lincoln, the office could now make use of double digit staffing during major events. The WFO reaches all of the 35 counties they are responsible for through the assigned nine NOAA Weather Radio All-Hazards transmitters (increased from three transmitters prior to 1995). WFO Lincoln provides increased communication with emergency management and media partners, as well as other customers, well in advance of an event.

All of these changes would come into play during operations on 13 July 2004.

3 WARNING OPERATIONS AT WFO LINCOLN ON 13 JULY 2004

One major aspect of the training produced by the WDTB is the emphasis on post-event analysis and the need to understand from past events in order to improve operations in the future (WDTB, 2002). The remainder of this abstract demonstrates the usefulness of a post-mortem analysis.

The overall meteorological aspect of this event was covered in Shimon et al. (2005) and will not be discussed here. This paper will focus on the decision making process employed and the critical logistical and human factors that impacted the service provided on July 13, 2004.

3.1 Expectations

The event was well anticipated several days in advance and that threat was communicated in several ways.

The Storm Prediction Center (SPC) outlook for Day Three (issued 11 July 2004) and the Day Two outlooks (issued 12 July 2004) included Woodford County in a slight risk of severe weather. The Day One outlooks issued on Tuesday, 13 July 2004, upgraded the area to a moderate risk of severe weather.

Hazardous weather outlooks issued by WFO Lincoln on 11 July and 12 July mentioned the possibility of severe weather on 13 July. The potential significant severe weather episode was highlighted in the outlooks issued at 1100 UTC and 1632 UTC on 13 July with a mention of the potential for widespread wind damage and tornadoes. The 1100 UTC outlook included an invitation to emergency managers and media partners to attend a conference call to discuss the potential event at 1600 UTC. The strong wording of these products prompted one local television station to request and receive permission to film in the WFO during the conference call. This conference call was conducted with fourteen participants including representatives of the Woodford County emergency services agency and local Peoria media.

SPC issued Tornado Watch 619 at 1552 UTC valid until 2200 UTC on 13 July. Although the single supercell in the region was still over extreme northwest Illinois, division of duties and workload were discussed using the WFO Lincoln Severe Weather Operations Plan (SWOP) (NWS, 2004) as a guide. The field crew from the television station requested that they be allowed to return later in the afternoon to collect film during the event for their early evening news broadcast.

3.2 Division of Duties

With the activation of the WFO ILX SWOP (NWS, 2004), staff members were initially assigned to the following positions:

a. Warning Coordinator (WCO) – Provides direction and coordination to the team ensuring adequate staffing levels and appropriate workload

b. Warning Meteorologist (WM) – Evaluates radar products in the context of the overall meteorological environment to determine the likelihood of severe weather. This person issues the appropriate products as needed.

c. Communication Person (COP) – Handles incoming calls and interaction with partners and customers, including acting as a liaison between the WM and the HAM radio unit regarding the relay and solicitation of reports. Assists WM as needed.

d. Data Acquisition – Performs routine data collection duties and assists COP in collecting reports from various sources. Also prepares real-time and summary Local Storm Reports.

e. NWR Operator – Monitors NWR to ensure that all products are disseminated correctly.

Additional personnel continued to function as the long-term forecaster and the short-term forecaster/meso-analyst. It was determined that the initial environment was not conducive to widespread flooding so that an optional flash flood analyst was likely not needed. At the onset of the event, hazardous weather was confined to a single isolated supercell approaching the WFO Lincoln warning area from the northwest. The initial decision was that only one WM was needed. This position is described as WM1 through the remainder of this abstract.

3.3 Event Decisions and Issues

As the supercell moved southeast toward the WFO Lincoln warning area, the staff made comparisons on several occasions with the August 28, 1990 Plainfield IL Tornado. As Merzlock (2005) pointed out, the high cape low to moderate shear environment was very similar between the two events as was the synoptic situation. The realization of the similarities heightened the sense of anticipation as the storm approached McLean County from the north.

Additional cells developed rapidly on the right flank of the main system. As they increased in coverage in the high cape environment, it was decided to sectorize by activating a second Warning Meteorologist (WM2) and COP to work storms to the west of the main supercell. At the time that the decision was made, the expectation was that the primary supercell would likely produce the most significant weather.

As the tornadic cell developed, it was monitored closely by WM2. The main focus of the overall warning team was still with the large moderate mesocyclone associated with the main cell. As the tornadic cell rapidly developed, WM2 noted some initial rotation and began to prepare a Severe Thunderstorm Warning for Woodford County. While preparing the warning, WM1 watching the supercell noted rapidly increasing rotation with the Woodford County storm and ensured that WM2 was aware. It was at this point that WM2 made what turned out to be a critical decision. Rather than abandoning the Severe Thunderstorm Warning he was preparing in favor of beginning work on a Tornado Warning, he decided to go ahead and complete the Severe Thunderstorm Warning. His thought process was to get a warning out quickly to alert Woodford County and then begin evaluating the need for a Tornado Warning on that cell.

The reception of the Severe Thunderstorm Warning at 1929 UTC activated the Severe Weather Plan at Parsons Manufacturing (Miller et al., 2005). Corporate "spotters" were sent out of the plant to scan the skies. It was these spotters that initially spotted the tornado to the west-northwest just as the Tornado Warning was issued (1934 UTC). If the WM had decided to abandon the Severe Thunderstorm Warning and began to evaluate the tornado threat, the Severe Weather Plan at Parson's would not have been activated for several more critical minutes, possibly leading to injuries or fatalities.

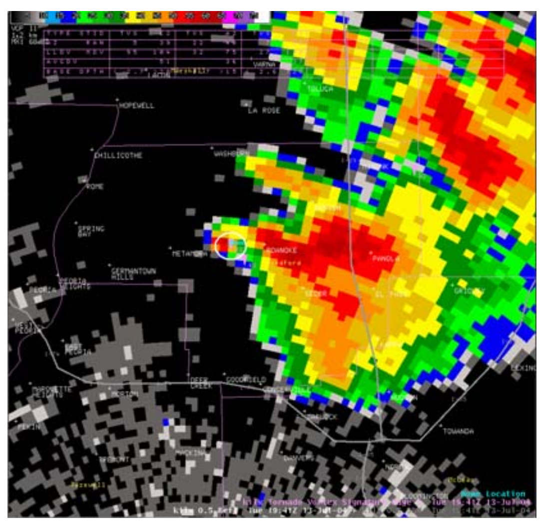

Figure 6 - KILX 1941 UTC 0.5 degree reflectivity image showing a "hook" echo enhanced with debris from the Parsons Manufacturing facility.

The F-4 tornado hit the Parsons Manufacturing facility at 1941 UTC, seven minutes after the Tornado Warning was issued and the initial formation of the tornado.

The rotation and reflectivity signature became much more pronounced as the tornado moved across central Woodford County. A debris-enhanced "hook" echo was evident in the KILX 0.5 degree reflectivity product as it moved away from the facility (fig 6). The COP and WCO worked with the volunteer HAM operator on-duty in an attempt to warn the town of Roanoke, now in the path of the tornado.

As the large initial supercell moved through Northern McLean County, it became more elongated and the moderate mesocyclone signature became more transient. It produced 10.75 cm (4.25 inch) hail in Hudson IL (Storm Data, 2004). With the strong echo observed in Woodford County and a recognition of how quickly the cell developed, there was a tendency to issue Tornado Warnings for rotational velocities lower than normally considered for Tornado Warnings through the remainder of the event. Fifteen tornado warnings were issued on 13 July 2004. The first three were verified with observed tornadoes (Storm Data, 2004).

At 2000 UTC, the COP asked the HAM radio operator for any new information from Woodford County. The response over the receiver was heard by everyone in the warning area, "All I know right now is that we are busy pulling survivors from the wreckage of a large manufacturing facility west of Roanoke". The impact of this statement on the staff was strong and immediate. After several moments of silence, the Acting Meteorologist-in-Change, who was also one of the WMs, asked for everyone's attention and then reminded everyone that we still had a job to do. This malaise, if allowed to go unchecked, may have influenced reaction speed among the staff during a portion of the remainder of the event. Although, not as intense, the effect on the WFO Lincoln staff was similar to what developed at WFO Norman OK during the May 3, 1999 Oklahoma Outbreak (Andra et al., 2001).

The television camera crew arrived several minutes later and was permitted to film the rest of the episode along with some of our follow-up information-gathering on the significant tornado. This added to the stress level of some of the staff members.

The large area of convection extending from eastern McLean County east into Vermilion County eventually produced an outflow boundary which raced southward along the Illinois/Indiana border. This outflow was not noted in the reflectivity data until it approached the KVWX WSR-88D. WM1 was slow to react to this transition due to the focus on circulations in the parent storm cluster. As a result several missed wind events occurred in southeast Illinois (Storm Data, 2004).

3.4 Post-event Findings

Finding #1:
The emergency manager/media conference call held prior to the event provided important information and insights to those expected to be impacted by the storm. A phone conversation allows two-way communication and questions to be asked that otherwise may not get answered.

Finding #2:
Forecasters should be periodically reminded of risk factors which contribute to non-optimal decision-making. In particular, decision-makers need to be reminded of potential biases. In this case, WM1 suffered from a Tornado Warning bias due to what occurred early in the event. As the environment changes the WCO and/or meso-analyst need to keep the WMs informed of potentially critical environmental information. They should not assume that the WM notices the changes just because they do. A second bias was propagated by the initial comparisons to the Plainfield Tornado of August 1990. The severe weather team was possibly overly focused on the main supercell to the detriment of the small cells developing to the west. These "secondary" cells developed on boundaries that focused and stretched environmental vorticity in the high cape environment.

Finding #3:
Although the WFO Lincoln Severe Weather Operations Plan suggests only a single COP, this event pointed out the utility to have a COP for each WM. The COPs were able to assist the WM with radar interrogation and provided a second opinion focused on the same concerns. This allowed for a building of consensus and possibly a reduction in any inherent bias present in the WMs warning process.

Finding #4:
The utility of allowing media and visitors in the office during an event has to be considered carefully. In this situation, the addition of cameras, although non-obtrusive, did increase anxiety levels among some of the staff.

Finding #5:
A large Situational Awareness (SA) display has been added to the warning area to provide SA to the entire forecast and warning team (fig. 7). Displays such as the one deployed at WFO Lincoln have been introduced effectively at other WFOs (Quoetone et al., 2004) to improve the warning process. The display as implemented normally shows the warnings issued by WFO Lincoln and

adjacent offices, as well as, KILX radar, and a mosaic of adjacent radar reflectivity. This type of display would have aided the warning team in noting the transition to a quasi-linear convective system as it moved south through eastern Illinois. In addition, a flat screen television has been added to the warning operations area to monitor local media and cable sources during significant events. Through the television we can monitor product dissemination and information being relayed by local broadcasters.

Figure 7 - WFO ILX warning operations area including the situation awareness display and media monitor.

4. CONCLUSIONS

Changes in technology, structure, and resource management have been significant over the past decade within the NWS. These changes have lead to a more efficient severe weather warning program in which outreach, training, logistics, and technology work together to promote the mission of the NWS which focuses on the protection of life and property and the enhancement of the national economy.

One valuable tool in this rapidly changing environment is the event post-mortem. A careful root cause analysis after an event can lead to improvements that can be reflected in future operations. 13 July 2004, in central and southeast Illinois is an excellent example of an event in which lessons can be learned to improve services.

5. ACKNOWLEDGEMENT

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