Service Assessment

EF5 Tornado in Parkersburg and New Hartford, Iowa

May 25, 2008

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Weather and Forecast Office – Des Moines, Iowa

Cover: Aerial view of damage caused by an EF5 tornado in Parkersburg, Iowa on May 25, 2008. Photo courtesy of John McLaughlin and Iowa Helicopter.

Contents

Preface

On May 25, 2008, a, large and destructive EF-5 tornado tore a 43-mile-long path across Butler and Black Hawk Counties killing nine people, injuring dozens and causing several millions of dollars worth of destruction.

The tornado began near the Butler and Grundy County line, 2 miles south of Aplington, Iowa at 4:48 pm CDT. The tornado grew quickly in size and intensity over the next few minutes as it approached Parkersburg. The tornado was nearly three-quarters of a mile wide as it moved through the southern end of Parkersburg at 4:56 pm CDT. A third of the town experienced devastating damage with nearly 200 homes destroyed.

The tornado maintained size and intensity as it moved toward New Hartford, Iowa. At 5:09 pm CDT, the storm moved just north of New Hartford, once again causing incredible structural and tree damage. The tornado weakened east of New Hartford with lesser damage as it pushed through portions of northern Black Hawk County, just north of the cities of Waterloo and Cedar Falls.

During this relatively weak phase of the tornado, the parent supercell storm produced significant straight line winds from a large rear-flank downdraft (RFD) just south of the tornado track. Wind speeds of up to 100 mph were produced by the RFD, with a wind gust to 93 mph at 5:37 pm CDT measured at the Waterloo Airport.

The tornado then re-intensified and grew to nearly 1.2 miles wide north of Dunkerton, Iowa causing substantial damage to a farmstead there. The tornado dissipated just before leaving Black Hawk County at 5:50 pm CDT.

The tornado was rated an EF-5 on the Enhanced Fujita Tornado Scale. This was the first EF-5 to strike Iowa since June 13, 1976 and only the third EF-5 tornado to occur in the United States in the past 10 years.

Tornado Facts:

EF Rating:	5
Path:	Around 43 Miles
Deaths:	9
Injuries:	50
Damage:	Millions of Dollars

Parkersburg Service Assessment Team

A service assessment team was formed shortly after the Parkersburg tornado to evaluate National Weather Service (NWS) products and services, internal operations, meteorology review and external response to the event. The Parkersburg service assessment team focused on three primary areas: external service and response, internal operations and NWS products and a meteorological review.

The service assessment team reviewed the event over the summer of 2008 and met in September to discuss best practices and findings, and to develop recommendations from the findings to improve NWS Des Moines operations in future events. It is the team's goal to accurately detail the National Weather Service's role in the event and to improve future operations.

Meteorological Review:

Marc Russell	Meteorologist, National Weather Service, Dodge City, KS
Rich Kinney	Meteorologist, National Weather Service, Des Moines, IA

Internal Operations and Products:

Craig Cogil	Senior Meteorologist, National Weather Service, Des Moines, IA
Brad Small	Senior Meteorologist, National Weather Service, Des Moines, IA

External Service and Response:

Jeff Johnson	Warning Coordination Meteorologist, National Weather Service, Des Moines, IA

Other valuable contributors and reviewers include:

Karl Jungbluth	Science and Operations Officer, National Weather Service, Des Moines, IA
Ben Moyer	Senior Meteorologist, National Weather Service, Des Moines, IA
Jeff Manion	Forecast Improvement Meteorologist, Central Region Headquarters, National Weather Service, Kansas City, MO

Acronym Definitions

AGL - Above ground level

AOP – Annual Operating Plan

ASOS—Automated Surface Observing System

AWIPS—Advanced Weather Interactive Processing System

CAPE—convective available potential energy

CIN – convective inhibition

CWA—county warning area

COVIP-County Visitation Program

DMX- National Weather Service Des Moines

DRC—descending reflectivity core

EC – Event Coordinator

EOC – Emergency Operations Center

FSI—Four-dimensional Storm cell Investigator

GFS—Global Forecast System model

GHG – Graphical Hazard Generator

GPS-Global Positioning System

HMT – Hydro Meteorological Technician

HWO – Hazardous Weather Outlook

IEMChat – Iowa State University's Iowa Environmental Mesonet IEMChat Project

LAPS—Local Analysis and Prediction System

LSR – Local Storm Report

MCD – Mesoscale Convective Discussion

ML – mixed layer

NAM—North American Mesoscale model

NWS – National Weather Service

ORPG/ORDA— Open Radar Product Generator/Open Radar Data Acquisition Unit

PDS – Particularly Dangerous Situation

PNS – Public Information Statement

QRT- Quick Response Team

RDA—Radar Data Acquisition Unit

RUC—Rapid Update Cycle model

SEOC – State Emergency Operations Center

SOO—Science and Operations Officer

SPC—Storm Prediction Center

SRM—Storm-Relative Mean Radial Velocity

STF - Short Term Forecast

SVR – Severe Thunderstorm Warning

SVS – Severe Weather Statement

TOR – Tornado Warning

UTC—Universal Coordinated Time

WCM – Warning Coordination Meteorologist

WCN – Watch County Notification

WFO – Weather Forecast Office

WSR-88D – Weather Surveillance Radar 1988 Doppler

NWS Products and Services

Methodology

National Weather Service (NWS) products from Weather Forecast Office (WFO) Des Moines and the Storm Prediction Center (SPC) were reviewed for the previous seven days leading up to the event. Products for Butler, Bremer, Grundy and Black Hawk Counties, in the proximity of Parkersburg and New Hartford valid for May 25, were reviewed for content, format, grammar and timeliness. This included Hazardous Weather Outlooks (HWO), SPC outlooks, mesoscale discussions and watches, NWS Des Moines Tornado Warnings (TOR), Severe Thunderstorm Warnings (SVR), Severe Weather Statements (SVS), Local Storm Reports (LSR), Hydrologic Outlooks and Short Term Forecasts (STF). Various qualitative statistics were computed to gage NWS performance versus established policy.

The NWS also communicates with many different entities before, during and after severe weather events. Any contact with the media, emergency managers, spotters, amateur radio operators, law enforcement, fire departments, and other entities was logged. Delays between the time of event occurrence and LSR transmission, and NWS receipt of the report versus LSR transmission were both computed. Similar to the product review, only contacts relating to the Parkersburg and New Hartford storms were compiled. Conversations not related to the event were omitted.

All the NWS products and contact information were assimilated into chronological order generating a timeline of the event and the days leading up to it. The timeline is available with this assessment in spreadsheet format. All NWS products, with the exception of STFs and Hydrologic Outlooks, have clickable hyperlinks which display archived radar data, graphical plotting, and/or text from the SPC or Iowa State University's Iowa Environmental Mesonet. The timeline is available here.

Facts or Quantitative Findings

- Average SVSs/Warning (total) = 1.73
- Average SVSs/SVR Warning = 1.20
- Average SVSs/TOR Warning = 2.17

- 81 products sent between 300 pm and 100am or 8.1/hour
- 7 Short Term Forecasts between 300 pm and midnight or 0.78/hour

- Event to LSR Lag – Time it took from event occurrence to LSR transmission
    - Average = 44 minutes
    - Median = 12 minutes
    - Min = 3 minutes, Max 6 = hours and 53 minutes

- Report to LSR Lag – Time it took from NWS receiving report to LSR transmission
    - Average = 12 minutes
    - Median = 10 minutes
    - Min = 2 minutes, Max = 1 hour 2 minutes

- Event to Report Lag – Time it took contact to report event to NWS
    - Average = 4 minutes
    - Median = zero
    - Min = zero, Max = 1 hour 6 minutes

- DMX Hazardous Weather Outlook identified "all modes of severe weather" possible on Day 5. SPC outlook noted "multiple day threat for relatively widespread severe storms."
- SPC Day 4 outlook noted "shear favorable for severe/supercell storms." Tornadoes mentioned in Day 4 HWO on the Thursday before the event.
- Day 3 SPC outlook continued to highlight supercells and a few tornadoes.
- Day 2 SPC outlook mentioned increasing low-level shear favorable for isolated tornadoes. The possibility of strong tornadoes was mentioned but in Wisconsin rather than Iowa. Spotter activation "probable" in DMX HWO.
- Day 1 SPC outlook "tornado supercells, some strong into upper MS valley." Spotter activation likely per DMX HWO. HWO updated at 831 AM to add conference call notification.
- All staff felt adequately prepared and trained to handle this high-impact event. Severe weather training in DMX paid dividends in individual abilities to complete necessary tasks competently.
- Local office policy states 2 SVSs should be issued per warning, while we averaged 1.73 overall, 1.2 for SVRs and 2.17 for TORs. Local office policy states one STF should be issued per hour, while we averaged 0.78 per hour or just less than one every 77 minutes. Many SVS updates, above and beyond office policy, were provided during the highest impact tornadic events. Considering the high product flow of warnings, statements and LSRs, just over one STF every hour and 15 minutes seems sufficient considering their low priority.

Best Practices:

- Amateur radio net control operator activated well ahead of time. Amateur radio operators were among the first to report a tornado.
- IEMChat was utilized throughout the event. KWWL TV was commended for their efforts which helped the warning service tremendously. Over thirty contacts into WFO DMX were made via chat or the phone, primarily chat, between 500 pm and 1000 pm.
- Emergency manager conference call was held at noon to inform officials of the escalating severe weather threat and need for heightened awareness**.**
- Staffing considerations prior to the event were excellent. Staffing decisions were initiated 48 hours prior to the event and were followed up with additional calls to ensure availability. Given the limited staffing available due to annual leave considerations, this was an invaluable step.
- Additional staff was called into the office prior to convective development. This allowed plenty of time to build situational awareness and spin up for severe weather operations.
- Rotation through the high-intensity positions, primarily the warning decision radar operator, was maintained with no shifts longer than 5 hours. It remains important to keep fresh people rotating through W1 to maintain high situational awareness, especially during high-impact events.

Findings:

- Finding 1: - Several products with spelling or grammatical errors and confusing verbiage were noted over the seven-day time period.
- Recommendations 1: – Encourage staff to proofread and spell check products before transmission, especially in instances that are not time critical.

- Finding 2: **–** Initial SPC Day 1 outlook mentioned "threat for tornadic supercells…some strong" with a 10% tornado probability. HWO wording had been mentioning isolated tornado potential for several days, but did not reflect the increased tornado threat. The morning Day 1 update diminished the tornadic potential, favoring straight line winds, but was raised again with the 1243 pm Mesoscale Convective Discussion (MCD) and subsequent Particularly Dangerous Situation (PDS) Tornado Watch and Day 1 outlook update. STFs did not highlight this trend either.

- Recommendation 2: - WFO personnel should be more aggressive and not be afraid to introduce stronger wording as situations dictate. Update STF, HWO, Watch County Notification (WCN), and then the Weather Story to reflect current thinking with “strong tornado”, “outbreak” or appropriate wording when a PDS Tornado Watch is valid.

- Finding 3: – Several severe criteria reports were never transmitted via a Local Storm Report (LSR). Likewise several LSRs were sent with no corresponding log sheet entries. Information was not disseminated and documentation apparently misplaced. Other log sheet entries were illegible.
- Recommendation 3 – Implement electronic logging which will keep track of all contacts. A very robust solution is already under development (http://ams.confex.com/ams/88Annual/techprogram/paper_135132.htm, and (http://ams.confex.com/ams/88Annual/wrfredirect.cgi?id=7624). Software will be reviewed prior to 2009 convective system and it may be added as a 2009 DMX Annual Operating Plan (AOP) goal if the software is available.   In the meantime, care must be given in completing log sheets and undergoing quality control by the Warning Coordination Meteorologist (WCM).

- Finding 4 – “Cutshaw Bridge State Acce” was used as an anchor point in a SVS. Actual location should be Cutshaw Bridge State Access Area which was truncated in the product. This location should not be available to WarnGen and especially not as an anchor point.
- Recommendation 4 – This entry and other similar database entries should be quality controlled, in terms of length of string and priority versus anchor points.

- Finding 5 – Confusing watch statements were included in several products. “A tornado watch remains in effect until 1000 pm CDT Sunday evening for Iowa. A tornado watch also remains in effect until 900 pm CDT Sunday evening for northwestern Iowa.”
- Recommendation 5 – Remove all automated watch insertions and leave only for manual insertion during tornado warnings or associated SVSs. WarnGen bullet would be plainly marked and easy to insert.

- Finding 6 – There were a few instances where phrases more common to meteorologists than the public were used, such as “severe weather modes” and “wedge tornado.”
- Recommendation 6: – NWS staff are encouraged to use common phrases such as “large and violent tornado” and specifically outline the severe weather threat (tornadoes, damaging winds and large hail are all possible). Avoid weather jargon.

- Finding 7: – At times, STF wording conflicted with current weather and NWS suite of warning products. "Scattered thunderstorms will develop slowly over the area" was included in the product while severe thunderstorm and tornado warnings were valid for the same area and tornadoes had already hit Parkersburg and New Hartford.
- Recommendation 7: – NWS staff should ensure that consistency exists among all products and current weather.

- Finding 8: - The lack of a designated Event Coordinator (EC) meant that warning teams were changing warning sectors on their own, often in a rapid manner. This led to some confusion among the people in operations.
- Recommendation 8: – In the event of no EC, it is the responsibility of the senior forecaster to coordinate warning sectors and ensure the entire staff has the necessary sector information. A display board or sector board may be necessary to track the sectors. All staff members should also know who is working as the current EC. When assuming the EC position, the EC should notify all staff members of his or her position.

- Finding 9: - The warning team involved with the Parkersburg tornado was not tracking their warnings via a log sheet or by any other means. The initial tornado warning almost expired without a downstream warning being issued for the Parkersburg storm.
- Recommendation 9: – It is the responsibility of the Warning Meteorologist or designee, usually the Warning Assistant, to know the expiration time of the warnings that he/she issues. Warning locations and times can be followed using the blue sheet provided in the operations area or the Graphical Hazard Generator (GHG) monitor on the AWIPS workstations.

- Finding 10: - Many individuals worked over 8 hours with three individuals working 14 hours or more, raising concerns of fatigue or weariness.
- Recommendation 10: - Although some consideration needs to be given for consecutive hours being worked, flexibility needs to be maintained, especially during times of peak leave.

- Finding 11: - There was confusion during one of the transitions of the Warning Meteorologists due to lack of spin-up time and situational readiness. The confusion led to warning expirations being missed.
- Recommendation 11: - Transitions can be made more orderly by placing the oncoming Warning Meteorologist in the Warning Assistant position for a brief period to gain situational awareness prior to assuming the Warning Meteorologist position.

- Finding 12: - As damage reports started coming in, awareness of the magnitude of the situation was not apparent to all staff.
- Recommendation 12: - The EC or senior forecaster should ensure that all staff is informed of an ongoing major disaster.

- Finding 13: - Finding quality latitude/longitude information for inclusion into timely LSRs was difficult during peak periods.
- Recommendation 13: During the County Visitation Program (COVIP), determine the capabilities of dispatch centers. Train for latitude and longitude queries and look into software programs that will make it easier and quicker to find latitude and longitude information. During high-volume events, prioritize reports emphasizing those with the greatest impacts such as tornadoes, extensive wind damage and very large hail.

- Finding 14: - The usage of "Tornado Emergency" was discussed during the middle of the Parkersburg tornado but was not exacted or included in products.
- Recommendation 14: - There is no national, regional or local policy regarding this product. The office needs to determine the viability of this product prior to severe weather so as to not distract warning operations during high-end events.

External Summary of Events and Operations

Emergency Management Conference Call

An emergency management conference call was scheduled at around 9 AM on May 25, 2008 for severe weather potential that afternoon and evening. There was only a SPC slight risk in the Day 1 outlook. However, it was a "high-end" slight risk and the middle of a holiday weekend so it was decided to have a call anyway to increase emergency managers' situation awareness.

The call took place at noon and there were no technical issues in disseminating the call notification. Twenty-nine emergency managers were on the call which highlighted severe weather potential north of Highway 20 early and CWA wide by evening. The Bremer, Butler and Black Hawk County emergency managers were on the call.

Bremer, Butler and Black Hawk County emergency managers all stated in their assessment input that the conference call was extremely useful. The Bremer and Butler County emergency managers were both out of town and they had no situational awareness of the severe weather potential.

Media Response and Service

Coverage during the Event

KWWL
From all accounts, KWWL did an outstanding job providing warning information for their listeners. The Chief of Police of Parkersburg stated he got much of his warning information from KWWL's coverage. The NWS and KWWL exchanged information on IEMChat (below) which was useful to both parties.

Radio
The major AM station in Des Moines (WHO) broadcasted warnings during the event. It is unknown if they had continual coverage.

Feedback from KCNZ radio in Cedar Falls indicated they provided listeners with wall-to-wall coverage. They were very complimentary of NWS products and services which enabled them to inform their listeners real-time. They stated they used all NWS outlook, watch and warning products.

Des Moines TV Market
The tornado occurred on the edge of the viewing area for the Des Moines market. The local stations were monitoring and broadcasting information on their stations. Feedback from WOI TV was very positive about NWS product flow during the event.

Media Chat
IEMChat was extensively used during the event. Here is the media chat log from 4:30 P.M. to 5:30 P.M. on May 25, 2008:

[21:42:26] <nwsdmx6@iemchat.com/Pidgin> FYI: spotters reporting rotating wall cloud now with that cell south of Ackley

[21:42:55] <kcci_wx2@iemchat.com/Gaim> baron scits would support that

[21:52:16] <kcciblack@iemchat.com/Gaim> back up sorry

[21:59:57] <nwsdmx4@iemchat.com/Pidgin> amateur radio says possibly 2 tornadoes E of applington.

[22:01:57] <nwsdmx4@iemchat.com/Pidgin> spotter says large tornado passing east of Parkersburg...may have hit south end of town.

[22:15:12] <nwsdmx4@iemchat.com/Pidgin> 2 mi sw of New Hartford...ISU spotters report second large tornado.

[22:18:09] <kwwl_stormteam@iemchat.com/Home> Viewer has softball size hail Finchford at 5:15 PM

[22:18:26] <nwsdmx4@iemchat.com/Pidgin> thanks kwwl but not good news.

[22:23:08] <kwwl_stormteam@iemchat.com/Home> Golfball size hail Finchford at 5:20

[22:25:23] <kwwl_stormteam_2@iemchat.com/Home> viewer call ....golf ball hail in Denver, Ia

[22:26:17] <nwsdmx4@iemchat.com/Pidgin> 522 pm...NWS employee NW of Cedar Falls reported that second satellite tornado had lifted. could not confirm larger leading tornado in dark area to his east.

[22:26:24] <kwwlremote@iemchat.com/Home> sirens going off in Cedar Falls

[22:26:30] <kcrgcedarrapids2@iemchat.com/Gaim> any more info about parkersburg damage at all?

[22:27:45] <kwwl_stormteam@iemchat.com/Home> Golfball size hail reported in Denver 5:25 PM

[22:27:57] <kwwl_stormteam_2@iemchat.com/Home> spotter just called in and said he sees a large tornado on the ground in black hawk co. intersection of C 57 and Hwy 218

[22:28:01] <nwsdmx4@iemchat.com/Pidgin> thanks kwwl. Yes, TOR was expanded into Cedar falls to be safe.

[22:28:09] <nwsdmx4@iemchat.com/Pidgin> Roger on tor report.

[22:29:04] <kwwlremote@iemchat.com/Home> Not pretty here in CF

[22:29:13] <kwwl_stormteam_2@iemchat.com/Home> got hail mark?

[22:29:26] <kwwlremote@iemchat.com/Home> nothing yet just gusty wind

Post-Event Coverage

KCCI television was very active in the post-storm phase of the event. Support from Iowa Helicopter in aerial storm survey pictures was extremely useful in the storm survey.

KWWL television provided excellent information about initial and post-event damage reports from the impacted areas. Information included injury and death information.

National Weather Service Internet Service

A news story was placed on the WFO Des Moines website during the morning of May 25th for severe weather potential during the afternoon and evening. Normally, the story would be a link to the warning page. However, due to a problem at Central Region Headquarters, the linking feature failed to work. Instead, a news story which had separate links was included. Later, the news story was changed to the normal link to the warning page after the problem was fixed.

Emergency Responder and Community Response Timeline

The following NWS product versus emergency responder actions timeline is based on several external sources including emergency manager, city police, fire department and emergency responder feedback.

Time	Event / Action
12:00 PM	DMX Emergency Manager conference call. Twenty-nine emergency managers on the call including all impacted counties. Butler and Bremer County emergency managers were not in their counties and were some distance from their counties.
3:30 PM	Tornado Watch 363 for much of Iowa including Butler and Black Hawk Counties.
4:04 PM	Formal amateur radio SKYWARN net declared by net control at DMX.
4:22 PM	Tornado Warning valid until 4:45 PM which included Aplington and Parkersburg.
Approx 4:25 PM	Butler County dispatch deploys spotters in the Aplington area.
4:46 PM	Tornado Warning for northern Grundy, southeast Butler Counties with Parkersburg specifically mentioned. Spotters in the Parkersburg area were activated. Several had already deployed independently.
4:48 PM	Tornado south of Aplington. Reported by three different sources in less than two minutes including amateur radio, law enforcement and independent spotters.
4:51 PM	Based on spotter reports south of Aplington by the Fire Department, the Parkersburg Fire Department sounds Parkersburg sirens. Sirens were not sounded based on NWS warnings or products, but by visual confirmation.
4:56 PM	Tornado enters Parkersburg.
5:04 PM	Tornado Warning for northern Black Hawk and Bremer Counties. Warning included most of northern Black Hawk County north of Cedar Falls and Waterloo, but only the northern part of Cedar Falls and not Waterloo. Tornado sirens in Waterloo and Cedar Falls were not sounded at this time.
5:09 PM	Warning assistant from responsible warning team made an outbound call to the Bremer County emergency manager. Based on a follow-up visit, the emergency manager was on the road and did not know about the warning. He called the county dispatch center about the warning. The dispatch center had a communication problem (Iowa system was apparently down for a short time). It is unknown if the Cedar Falls Warning Point called the county to relay the warning. If they did, it was after the 5-minute time frame from

	the warning to the outbound call by the warning assistant. The emergency manager much appreciated the call. Spotters in the Janesville and Waverly areas were deployed. Siren activation is not known.
5:09 PM	Tornado moves through the New Hartford area.
5:21 PM	Tornado Warning issued for most of Blackhawk and southern Bremer Counties including the Waterloo and Cedar Falls area. This warning was issued to specifically include all of Waterloo and Cedar Falls since the storm was starting to make a slow right turn.
5:26 PM	Cedar Falls and Waterloo sirens were sounded based on second warning. Sirens were sounded by the County Emergency Operation Center (EOC) by the emergency manager and not the dispatch center.
522 PM-550 PM	Tornado moves into northern Black Hawk County and continues east producing damage north of Cedar Falls and Waterloo.
537 PM	Tornado Warning issued for northern Black Hawk County including Waterloo and Cedar Falls.
558 PM	Tornado dissipates just before entering Buchanan County.

County Emergency Management, City Officials and Fire Department Actions

Information based on written feedback and interviews with emergency managers, dispatch offices and the Parkersburg Police Chief.

Butler County

Butler County emergency manager was out of town at the time of the noon conference call, but participated in the call. Based on his feedback, he did not use NWS products to respond to the tornado. Actions taken by Butler County were made by the county dispatch center and individual town fire and police departments. NWS called the emergency manager during the evening to coordinate storm survey actions the following day.

According to the Butler County dispatchers on duty, they followed their local procedures concerning spotter deployment. Sirens were activated when spotters in the Aplington area observed a tornado. No severe weather calls were made to the NWS. Warnings were received via the Iowa System and EM 911 Chat. One dispatcher used EM 911 Chat, but the remainder didn't. No messages were sent on EM 911 Chat. The dispatchers stated that they had no idea about the seriousness of the situation. The dispatchers used NWS warnings for spotter activations, but not siren activation.

Bremer County

Bremer County emergency manager was out of town at the time of the noon conference call. He was returning to his county at the time of the tornado and received a call from Weather Forecast Office (WFO) Des Moines. Based on that call he took action to coordinate the dispatch center and spotter groups. The Janesville Fire Department deployed according to the emergency manager.

Black Hawk County

Black Hawk County was on the noon conference call and had a command center or EOC active during the event. During the storm event, the EOC maintained communication with the NWS via phone, deployed spotters and sounded sirens. After the event, the EOC evaluated damage and intensity. On Tuesday, May 27th, the NWS Des Moines Meteorologist in Charge attended a Black Hawk County Board of Supervisors meeting which was helpful for the board.

Parkersburg Police and Fire Department

Parkersburg installed a new siren system four days prior to the storm and it was tested the day before the event. The new siren saved lives since it increased the reach and effectiveness of the siren system in Parkersburg. The new siren system can be activated remotely. However, new protocols were not in place and the system was manually activated for the Parkersburg event.

City officials got warning information from the county dispatch office and KWWL. They did not mention NOAA All Hazards Radio. They did not know that the tornado watch was a PDS tornado watch.

Response after the event was tremendous. Aid came in from surrounding jurisdictions rapidly.

Christopher Luhring, Chief of Police, wishes to partner with the NWS in outreach activities for tornado safety and expressed interest in speaking at the 2009 National Weather Association Conference.

Other fire department feedback mentioned using NWS products to determine appropriate response. The Dunkerton Fire Department received information from NOAA All Hazards Radio.

Recent NWS visitation and Training Record

Recent County Visit Program (COVIP) Visits:

Black Hawk County

Emergency Management	November 2006
KOEL Waterloo	December 2005
Waterloo Courier	October 2005

Butler County

Emergency Management	May 2007

Bremer County

Emergency Management	October 2006
KWAY Waverly	October 2006
Waverly Paper	October 2006

Recent Spotter Training and Outreach Talks

January 24, 2008	Outreach School Talks, Clarkesville, Butler Co	45
March 3, 2008	Spotter Training, Allison, Butler Co	25
March 11, 2008	Spotter Training, Waterloo, Black Hawk Co	46
March 12, 2008	Spotter Training, Janesville, Bremer Co	51
April 25, 2008	Preparedness Talk, Waterloo, Black Hawk Co	25
May 3, 2008	Media Conference Presentation, Waterloo	150

State Emergency Operations Center (SEOC)

Coordination between the SEOC and the NWS occurred during the evening hours of May 25, 2008. The discussion included a request by the NWS for a Civil Air Patrol aerial survey of the damage. An NWS representative was sent to the SEOC for a period of time on May 26, 2008 to support SEOC operations. The detail was only for one shift and the NWS was released by evening.

External Response Summary

The overall spotter and emergency management response was mixed. There were examples of excellent emergency management operations such as Black Hawk County having an EOC operational during the event. The response in Butler County to the tornado warnings and the tornado itself came from the Butler County dispatch office, the sheriff's office and by the individual town/city policy and fire departments. The Butler County Emergency Manager had no direct role, or function, in the tornado event during the warning phase. Contact was made several hours later to discuss the event and coordinate the damage survey.

Storm Survey

After the Parkersburg tornado ended, it became obvious that a storm survey would be needed the following day. A storm survey team was organized and emergency managers notified during the evening of the 25^{th}. Karl Jungbluth, Science and Operations Officer (SOO), Jeff Johnson, (WCM) and Brad Fillbach, Hydro-Meteorological Technician (HMT) were the initial survey team.

A notification Public Information Statement (PNS) was issued and a web story generated, per WFO Des Moines policy, stating that a survey team was being deployed.

The survey team arrived in Parkersburg by 1000 AM, Monday, May 26, 2008. Greater than EF-3 damage was apparent and WFO Des Moines was notified and asked to report that fact to NWS Central Region Headquarters to initiate a quick response team (QRT). The purpose of the QRT is to include more wind damage experts in the damage assessment.

The survey team spent several hours in Parkersburg, New Hartford and in northern Black Hawk County surveying the track. Over forty damage indicators were indentified during the survey. The preliminary survey result was a low-end EF-5 tornado in Butler County in both Parkersburg and New Hartford. Widespread EF-2 damage was found in Black Hawk County as the tornado widened near the end of its life cycle.

The team was told by NWS Central Region Headquarters not to release its finding pending the QRT findings. The media were told that the final survey results would not be released until at least the afternoon of May 27, 2008.

On Tuesday, May 27, 2008, Karl Jungbluth, Roger Vachalek (forecaster), Partha Sarkar (Iowa State University) and the QRT expert (Todd Shea, WCM La Crosse, Wisconsin) met to confirm the survey. Donna Dubberke, WCM Quad Cities was also present to help survey. The survey results were coordinated with Jim Keeney, Dan McCarthy and National Weather Service Headquarters prior to the final EF-scale rating. The final rating was a low-end EF-5 tornado.

Brenda Brock, Meteorologist in Charge-Des Moines, was stationed at the Parkersburg Incident Command Post and participated in the Incident Command meetings while the storm survey team was deployed.

The results were released in a damage survey news conference in Parkersburg. The final rating was leaked prior to the survey news conference which created some media coordination problems.

Iowa Helicopter and the Civil Air Patrol surveyed the tornado route from the air. Their photos were very valuable in the final rating and in post-event documentation and research.

Best Practices

- Proactive emergency management conference call on a holiday weekend was very useful. Decision to make call went beyond local policy guidance.
- Calling dispatch centers and emergency managers was very useful and appreciated. Practice of county visitation to maintain good relations with response community is

necessary and WFO Des Moines should continue the COVIP. Primary emergency management call number should be maintained in COVIP county summaries.

- Great cooperation between WFOs and wind experts to arrive at the correct and accurate EF-scale rating. This included consulting with aerial survey pictures. Storm survey partners included John McLaughlin, Iowa Helicopter; Civil Air Patrol; Iowa Homeland Security and Emergency Management (funding Civil Air Patrol); Tim Marshall, HAAG Engineering; and Partha Sarkar, Iowa State University.

Findings and Recommendations

- Finding 15: There were some external complaints about not being able to report because DMX's toll-free severe weather report line was busy. Is there a way to expand our phone lines during severe weather or add an additional line we can utilize during severe weather? The toll-free 800 line was installed when land-line phones and long distance were the standard.
- Recommendation 15: WFO Des Moines phone system should have the toll-free 800 severe weather line roll over to other lines. This would increase the number of phone lines through which spotters can reach the office and avoid busy signals. The voice messaging service should continue if all lines are busy.

- Finding 16: Outreach to dispatchers is needed for storm-based warnings and siren/spotter deployment and activation. Dispatchers were unaware of NWS operations, products and services.
- Recommendation 16: Create an on-line, and CD/DVD presentation on NWS warning operations and storm-based warnings and distribute to WFO Des Moines counties by severe weather season 2009.

- Finding 17: Responders did not know that the tornado watch was a PDS watch. The PDS nature of the watch needs to be included in NWS dissemination and/or products.
- Recommendation 17: Included NWS products in training per Recommendation 16. Include PDS wording statement in all PDS watch WCNs, STFs and other WFO watch/warning products. Inform media and emergency management of this via media advisory and training. Refer to Recommendation 2.

- Finding 18: Counties which run severe weather operations during a high-end event through the dispatch center and not a dedicated EOC have extreme difficulties handling spotter reports, spotter activation, etc.

- Recommendation18: Encourage best practice of using EOC during severe weather during NWS outreach in COVIP visits, spotter training and through the StormReady program.

- Finding 19: Laptop Bluetooth method for Global Positioning System (GPS) surveying failed. The Bluetooth-enabled device failed to sync with the satellite. The laptop was not used for the survey. Paper forms and maps were used instead.
- Recommendation 19: Using mapping software applications, e.g., Google Earth and/or new hardware, develop a new method of entering storm survey information into a PC or handheld GPS unit.

- Finding 20: The QRT process was slow, delaying the final report for around 24 hours. The survey team on the first day was very experienced and their findings were accurate.
- Recommendation 20: Central Region Headquarters should consider the following changes to the current QRT process: Authorize more wind experts using clearly defined criteria, experience and training requirements. Use e-mail, conference calls, etc. to collaborate high-end survey results with wind experts to verify a tornado's final EF-scale rating.

- Finding 21: The final rating was leaked prior to the survey news conference.
- Recommendation 21: Tighten security of the EF-scale rating until released in a press conference, PNS or NWS Internet news story.

Appendix A - Testimonials

Charles E. Grassley, United States Senator

Thank you for the email message you sent me regarding the recent tornadoes, storms, and flooding in Iowa. It is hard to see friends, neighbors, and constituents in such hurt. However, I have been encouraged by the Iowa "can do" spirit. I appreciate all of the efforts Iowans have and will be doing to help each other.

My staff has met with folks from NOAA and the NWS in the Washington, D.C. area regarding the weather patterns leading up to these incidents and what may be expected the rest of the summer. Should there be further inclement weather, I will try to heed your advice and take shelter instead of standing by my window watching the tornado go by.

Iowa is faced with a long recovery process. I have been working with the rest of the delegation and other Midwest members to provide additional federal assistance. I will continue to do what I can to help Iowa come back stronger than before.

Please do not hesitate to contact me if I may be of assistance with any federal matter. My offices in Iowa, as well as in Washington, D.C., are here to serve you.

Sincerely,

Charles E. Grassley

United States Senator

David Miller, Administrator, Iowa Homeland Security and Emergency Management

I will let the rest of my staff speak for themselves.. some of them have a greater interaction with the NWS than others, and may have a different perspective. From my point of view, the NWS did an excellent job. Indications I received when touring with the Governor is that the NWS provided warning before the event that cause activation of local spotters. I spoke with a sheriff's deputy who said they did get notice, they did get the spotters out, they did spot the tornado and they did have time to take shelter. While the storm caused a number of deaths, every indicator I have is that the NWS did an excellent job of warning the community as far in advance as possible.

As you know we rely heavily on the NWS to provide not only watch and warning information but to provide us operational information during the storm which also occurred. Often times, a storm will take out communications with the affected areas and we depend on the NWS to help to quickly assess the level of damages and impact through the information that you see on the radars and through the information you receive for a variety of sources, including the media, dispatch centers, and citizens.

The NWS continues to provide us timely and relevant forecast information which has a significant impact on our ability to plan and take mitigation measures before a storm. We depend heavily on a number of tools that NWS employs. The severe weather forecasting and hydrological modeling are just two of the products that we rely on.

To you and all as that the NWS .. thank you for all you do.. You and your team are an intricate part of what we do..and I appreciate your dedication and performance.

WFO Des Moines Amateur Radio Net Control

This is a testimonial from Tom Reis, N0VPR, who was one of the net controllers at WFO Des Moines on May 25, 2008.

The day (Sunday May 25, 2008) started with a text message at 8:00am stating that there would be a 12 o'clock conference call discussion of the weather threat for the day. I later received an email from NAØR advising that he would be at the Johnston NWS office starting at 2:00pm and would like to finish at 8:00pm or so as he had to work early the next day. I replied that I'd come out at 7:00pm.

Usually on these days I monitor the local hub repeater and I also run my GR Level 3 radar software on my laptop. This helps me be better prepared when I go in. I see that the NWS has issued several severe thunderstorm warnings as well as tornado warnings for the NE edge of our county warning area. I also see we have cells moving in from Missouri as well. I finished my supper and headed in about 6:40pm.

Arriving at the NWS office I notice a few more cars than usual. (More cars = more meteorologists) and prospects of a busy night. I get buzzed in and I sign the visitors log book, 6:50pm. The operations room is active and Jim NAØR is on the radio. I check with the lead meteorologist and get a briefing on what is happening and what to expect. I set next to Jim so that he can brief me. It is important to know what spotters are out, where they are, the storm history and where the severe weather is now. Jim handles traffic while filling me in. He decides to stay for a while.

Reports are coming in about injuries in the Parkersburg tornado. It becomes a little more somber. We also have supercells popping up on the southern border of the state and in the western part of our 51 County Warning Area. We are fortunate to have a KCØUNH near Lucas. Jim takes his report and tells him where the strongest cell is. Roland KCØIEA calls on the radio to say he's available if needed.

Jim and I discuss the need to have Roland come in, probably not, was the decision. A closer look at the radar and all the areas involved prompts us to call him in anyway. Roland arrives to replace Jim. I brief Roland and we decide how we'll split the radio duties.

I start working the reports, we have cells building in Guthrie County and a tornado warning is issued. I get KBØJUL from Dallas Center in the proper position to get a good view while being careful not to put him in harm's way. I also have NØQIX coming out of Perry, I'll have him head south and wait. KCØJUL reports nickel size hail east of town. I am having trouble with his signal and move him to a closer repeater. This doesn't help much. I ask my partner to cover that frequency. A ham spotter asks where I can use him. I had to tell him I didn't have time to look for the best area, just let me know where he is. In the back ground I hear the communications desk getting a civilian report of hail from Guthrie County. KCØKDQ calls, he is heading west on Interstate 80. He observes a defining wall cloud with lowering to his NNW. I make sure that report gets to the warning team working those counties. More hail reports from the area.

The Warning Meteorologist announces that this is moving into the Des Moines area and that the phones will be ringing off the wall. They do! The NWS staff has now grown to 13. AC5DT in Ankeny reports ¾" hail 3 blocks from the Ankeny High School.

KCØKDQ has moved north and is now reporting strong updraft in Grimes. I get a report from KØCQ, Story County gust front with fingers. That report needs to get to the warning team for evaluation. The KCØKDQ report that the wall cloud is weakening and has lost its lowering. There is a station checking in from Wellsburg, but I am unable to copy. We spin the beam in that direction but are still unable to copy his report.

Brief lowering near the east Mixmaster, wall cloud reforming 3 miles east now, and additional updraft noted. Wall cloud is diminishing over Altoona. KCØNFA reports lowering but no rotation in Altoona. Report from Bondurant of quarter size hail. KB6SDI and KCØIEB go mobile on the south west part of part of Des Moines. NØBKB reports 67 mph winds measured 11 miles south of Stuart. Warnings go out for several counties including the Polk County for high wind. NØOOD is mobile on I35 in Ankeny. Somewhere in here I catch a storm report from KAØRDE on the fiber optic link to Taylor County. Roland and I are both catching reports on multiple frequencies. KB6SDI on the SW side calls in heavy rain, ¼" hail and winds in excess of 50mph. A minute later the communications desk operator reports 75mph winds clocked at the Des Moines airport. Wind damage reports coming in. NFØT reports pea sized hail in Conrad. We get several reports of power outages in Jasper County.

After dozens of SVR, (severe thunderstorm warnings) and several TOR,(tornado warnings). Things are beginning to wind down some. Tonight we have been active on all three radios to include six frequencies, and the fiber link. I hear the discussion a between a couple of NWS staff going home after an extended day as they will need to travel to Parkersburg tomorrow for post tornado assessment. As they leave they make sure to thank Roland and myself for coming in. The reports taper off, the radios start starring at us and the reality that some Iowans may have been lost in the Parkersburg tornado becomes evident. We decide to close the formal Skywarn Net and thank the spotters. The lead meteorologist decides that we can leave anytime and wants to be sure that we know that we are appreciated. After the last county warning expires we decide to head home. We'll leave the radio on low volume in case someone needs to report damage. We say goodbye and again we are thanked for our help. Sign out is at 11.40pm

The intent of this article is to illustrate the organization and cooperation that occurs during the weather nets. The Skywarn Net cannot survive without the timely reports of trained amateur spotters to accurately inform the meteorologists with "ground truth" information.

I apologize if my recollection of the events is not quite in order. I'm certain that I have forgotten to mention some other things as well. The other intent is to thank the staff at the NWS. They are without exception some of the most professional, dedicated and congenial people I know. Many of the staff are hams. Thanks folks.

KWWL TV, Waterloo, IA

"Nice job leading the team! Warnings were timely and information was shared quickly".

"I believe lives were saved as a result of your work. Well done!"

Jason Parkin, KCCI TV, Des Moines, IA

"I thought you guys did a tremendous job. Hard to beat a 37-minute warning. It'd be nice if we could all get together and look at some of the stuff that you saw on the ground. I'd like to learn more about how you assess damage.

Thx,JP"

Mark Bruggom, KICD, Spencer, IA

"I'll trust that you'll pass this along to the troops who were working Sunday during the nightmare of an EF-5 tornado. From all accounts, you can be proud of the professionals who were under the gun. But you already knew that.

Thought maybe I'd add my thanks from an area of the state that *wasn't* threatened. I was watching the development Sunday afternoon from here and was impressed with the data stream warning people.

Bet those working would be fine if this didn't happen again for a while!"

Dennis Shipper, 1112 Highway 57, Parkersburg, IA - EF4-5 zone

"That little $30 Weather Radio, it was right to a T!"

Michael Laake, Estherville, IA

"The report on the Parkersburg tornado is outstanding work. I also complement the diligence done on the warnings prior to the tornado hitting the different areas.

Some say weather persons get it right only half the time. It is times like this that prove how good you are. While we all have time when we fail, we should stand proudly when we do well.

You all did well. There are people alive today, who will complain about the weather, only because of your efforts."

Shawn, who works for Qwest in the Waverly area

"That weather radio is fantastic, it is really slick. It gave us a warning 2 and a half minutes before the TV gave us warning. I just had it set to alarm and it alarmed. You all did great, that weather radio rocks."

Jeff Kennedy, KWWL TV

"I thought everyone involved did a good job. Seemed like there was good communication and sharing of info."

Mike Zwier, KTIV News

"Our viewing area was not directly impacted by those storms… but I did spend some time that night following them. As a bystander, I would say you guys did a great job. It seemed like you guys did plenty of warning updates as new information and locations became available.

I'm really impressed with the great information that gets passed back and forth between your office and several of the other stations in your CWA through IEM chat."

Joe Milledge, GM KIIC-FM, Albia, IA

All too often, you hear of complaints that the wx service missed a forecast or other minor wx event, so when you look back over what happened in Parkersburg, you have to recognize that not only did you guys get it right, you got it EXACTLY right.

I have no doubt that the efforts of the WX service saved lives in that area of the state. I hope you are being recognized at the highest levels of state leadership for this. This could've been a much worse week in Iowa history.

Kudos for getting the warnings spot on and for getting the warnings out in time.

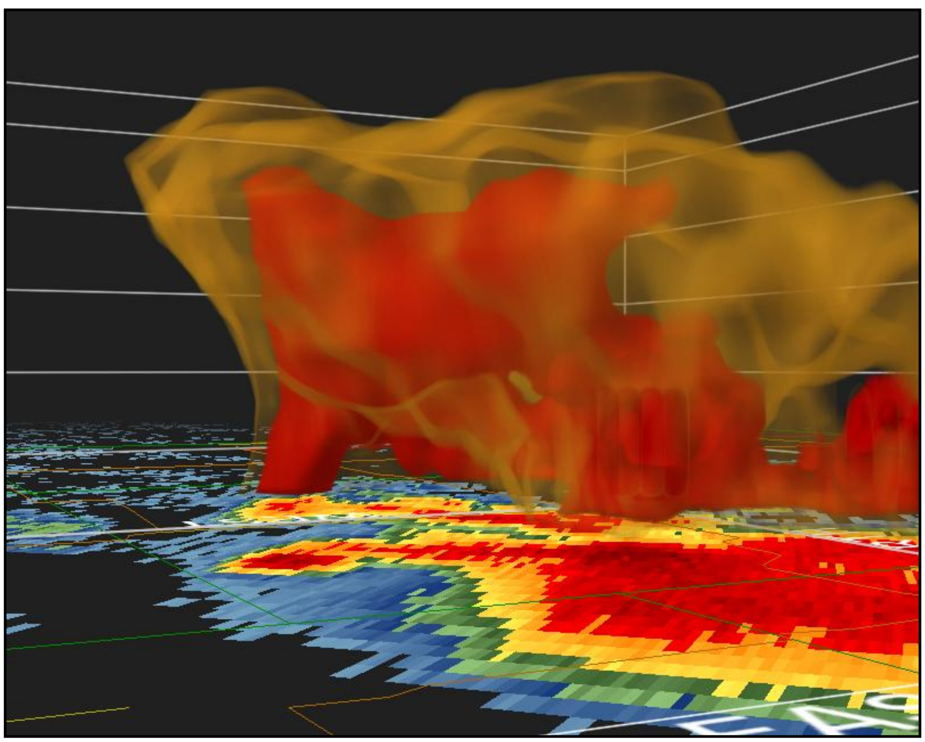
It provides comfort for communities like Albia and Ottumwa that our radio stations serve - that the WX service is highly technical, organized, and automated.

Good job.

Appendix B - Meteorological Review

Parkersburg – New Hartford EF5 Tornado

May 25, 2008



Overview

The Parkersburg tornado developed late on the afternoon of 25 May 2008, well south of a surface low that was located over northern Minnesota, and beneath moderate west-southwesterly flow aloft. Mesoanalysis graphics from the Storm Prediction Center (SPC) indicated upper-air divergence over a large portion of Iowa in the right-rear quadrant of the 300-mb jet (Fig 1). Short-wave troughs were embedded in the west-southwest flow at 500-mb (Fig. 2) and 700-mb (Fig. 3). 850-mb objective analysis indicated strong moisture transport and moisture pooling along an axis that extended into northeast Iowa (Fig. 4).

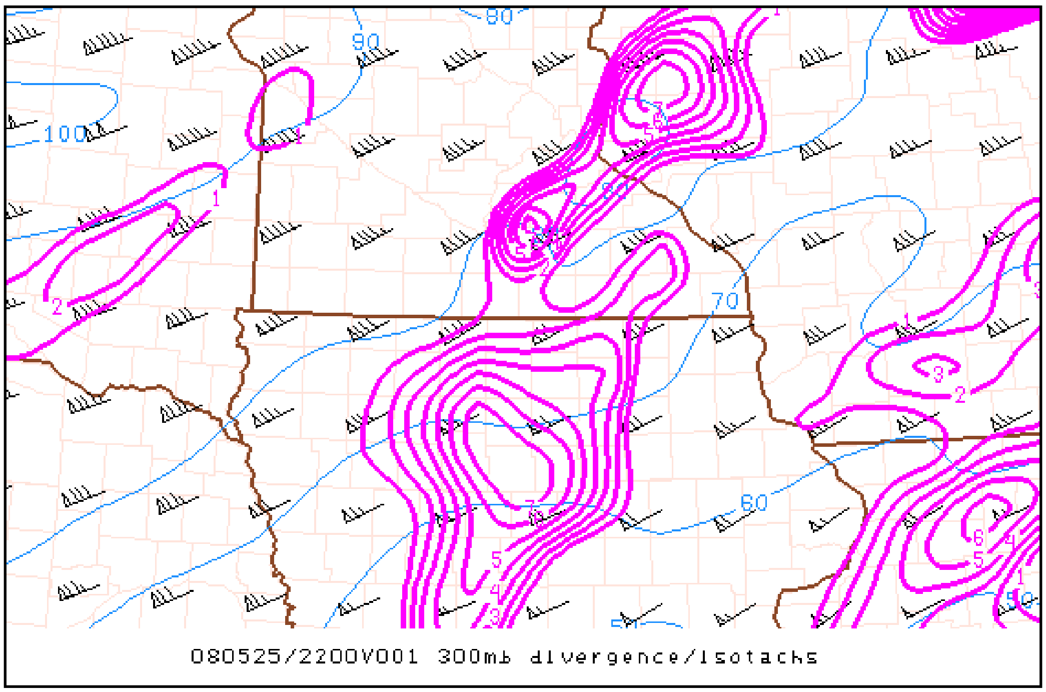


Fig. 1. 300-mb divergence/isotachs 2200 UTC 25 May 2008

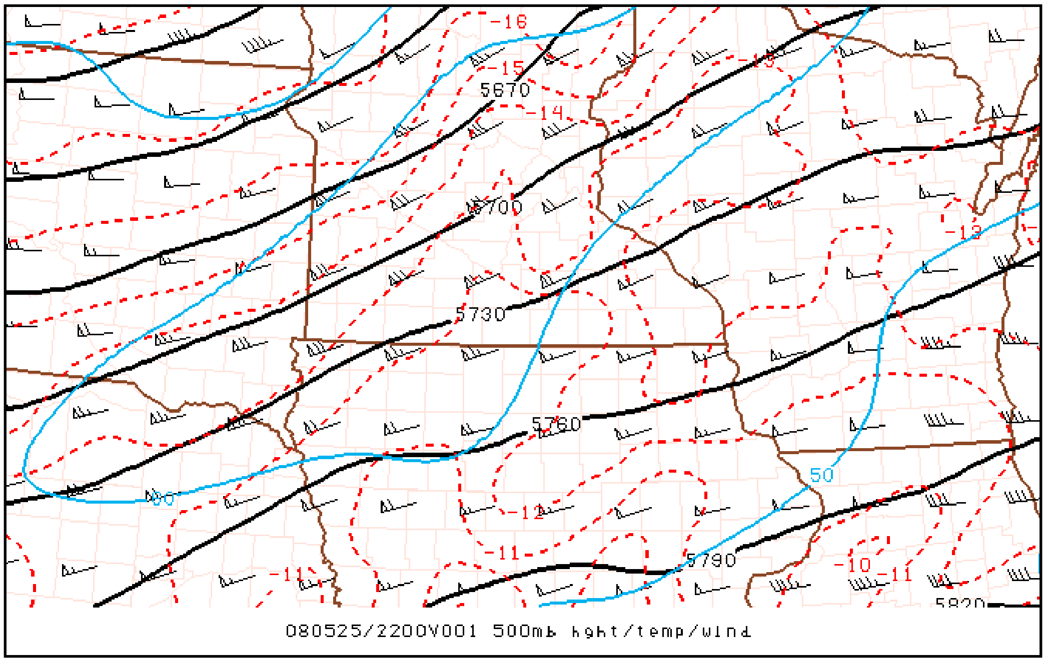


Fig. 2. 500-mb height, temperature, wind 2200 UTC 25 May 2008

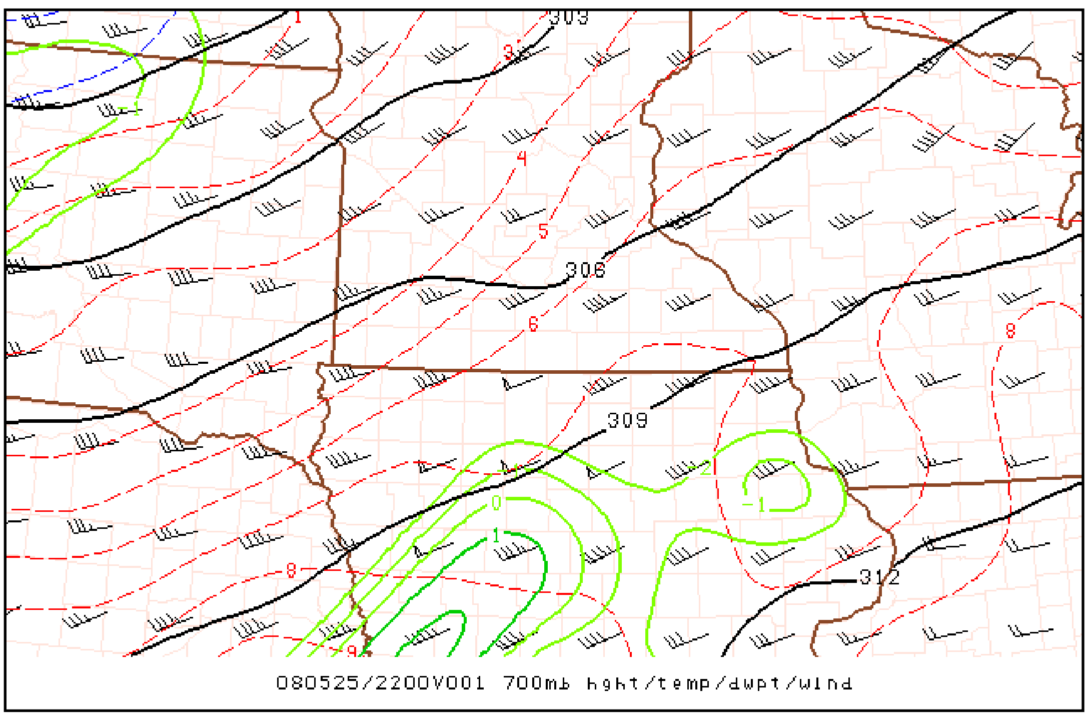


Fig. 3. 700-mb height, temperature, dewpoint, wind 2200 UTC 25 May 2008

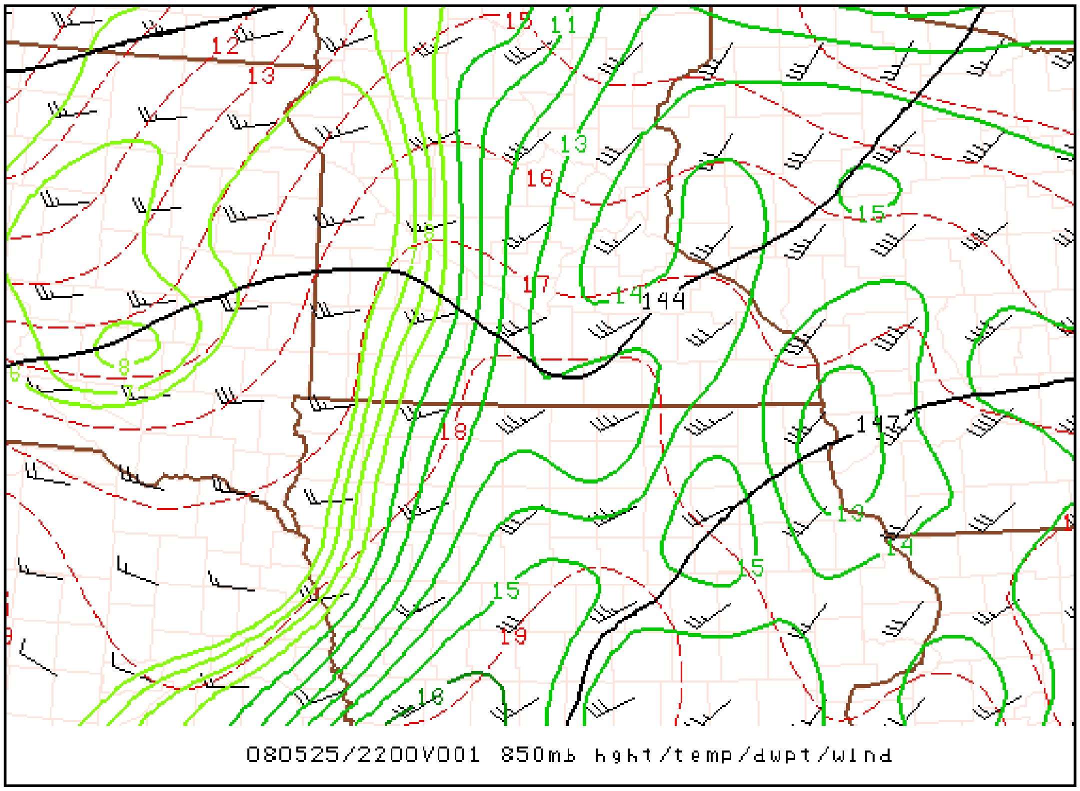


Fig. 4. 850-mb height, temperature, dewpoint, wind 2200 UTC 25 May 2008

Forecasters originally focused their attention near a triple point in south-central Minnesota, but that focus quickly expanded south after 2000 UTC as the environment became increasingly favorable for tornadoes over north-central Iowa. Mesoanalysis fields from 25 May 2008 showed that numerous thermodynamic and wind shear values were well within the range of concern for strong and violent tornadoes. Surface weather features of interest included a north-south-oriented warm front through central Iowa, and a cold front/dryline extending from the triple point into western Iowa and southeast Nebraska (Fig. 5).

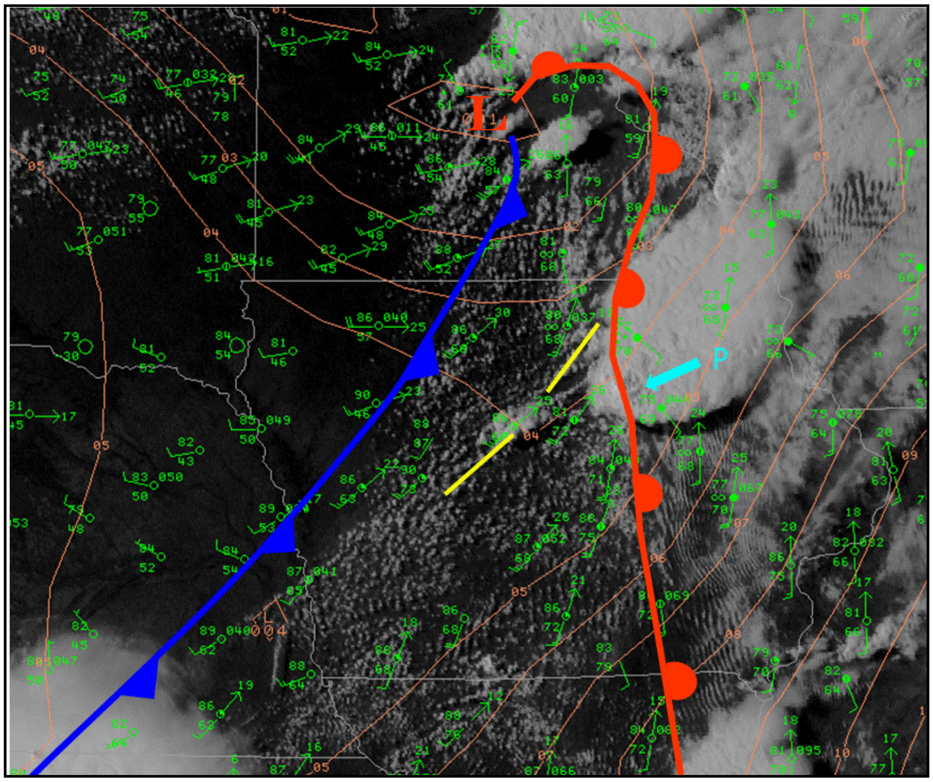


Fig. 5. MSLP, surface observations, surface analysis, and visible satellite imagery, 2200 UTC 25 May 2008 (cyan arrow indicates location of Parkersburg)

Weather conditions over central Iowa rapidly changed from cool, cloudy and humid during the morning, to the warmest, most humid afternoon of the spring season. Parkersburg residents commented that May 25th was the first humid, summerlike afternoon of the year. Clouds lingered longer over northeast Iowa, and the resulting differential heating reinforced the warm front near Parkersburg. A cluster of thunderstorms rapidly developed at 2000 UTC near Fort Dodge, Iowa (KFOD) within the northern end of the axis of highest instability, indicated by 100-mb mixed-layer convective available potential energy (CAPE) near 3000 J/kg. This development was not anchored upon the warm front or cold front, but appeared to be associated with a pre-frontal trough dividing much of the warm sector from a zone of deeper mixing and decreasing surface dew points to its northwest. Visible satellite imagery also indicated a gravity wave that initiated in south-central Nebraska earlier in the day. The initial storms developed just after this feature moved through. Storms at the southern end of the cluster quickly moved to the instability gradient at northeast periphery of the instability axis. The rapid northeast expansion of convection also appears to be linked with the gravity wave. Interaction with the north-south-oriented warm front began after 2100 UTC. The ensuing supercell thunderstorm remained tied to the north-south boundary as the tornado reached EF-5 intensity shortly before 2200 UTC (Fig. 6).

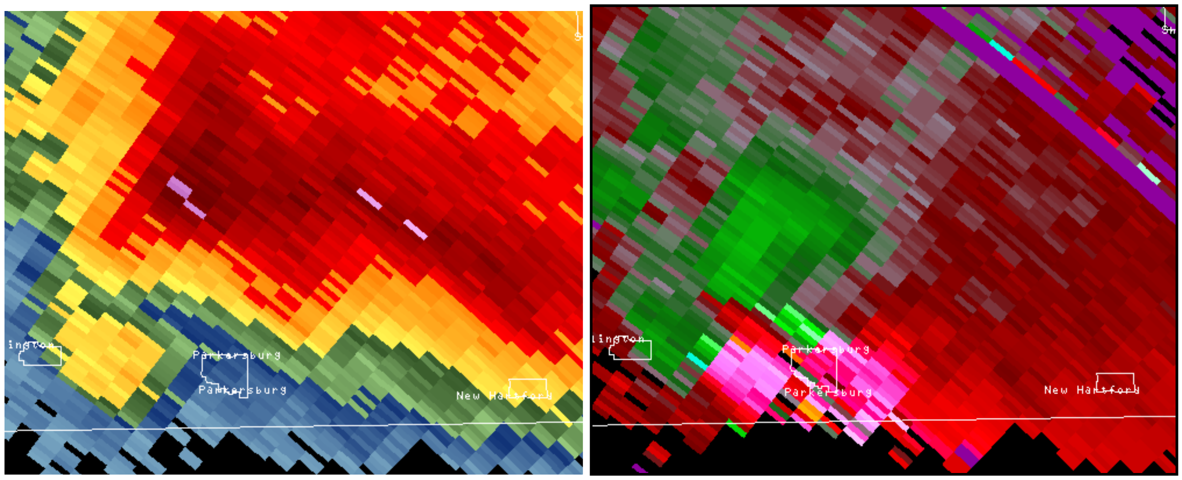


Fig. 6. 0.5 deg reflectivity and SRM 2155 UTC 25 May 2008, just before the tornado moved into Parkersburg

As the tornado pushed across southern Butler County, spotters reported a satellite tornado at 2207 UTC south of the main tornado (Fig. 7). This smaller rotation was not detected by radar.

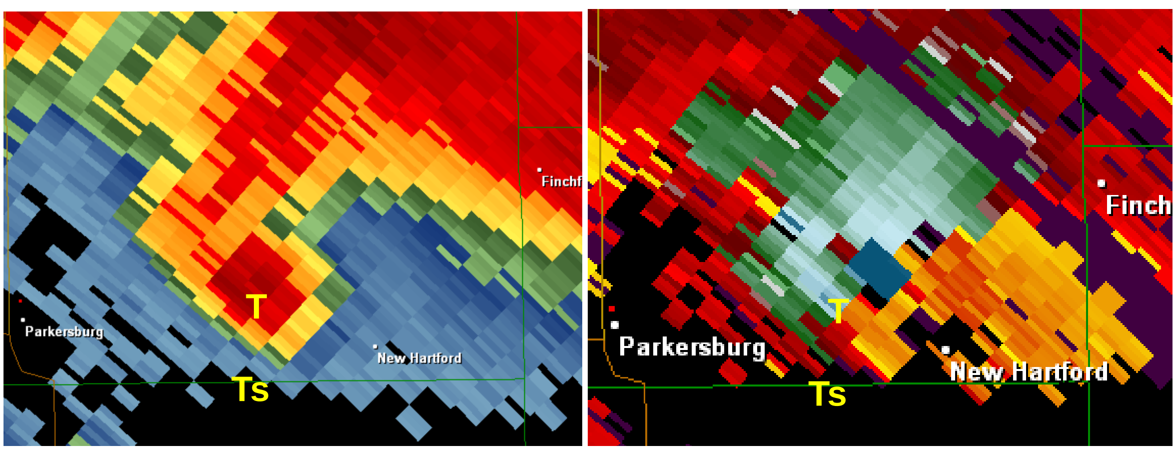
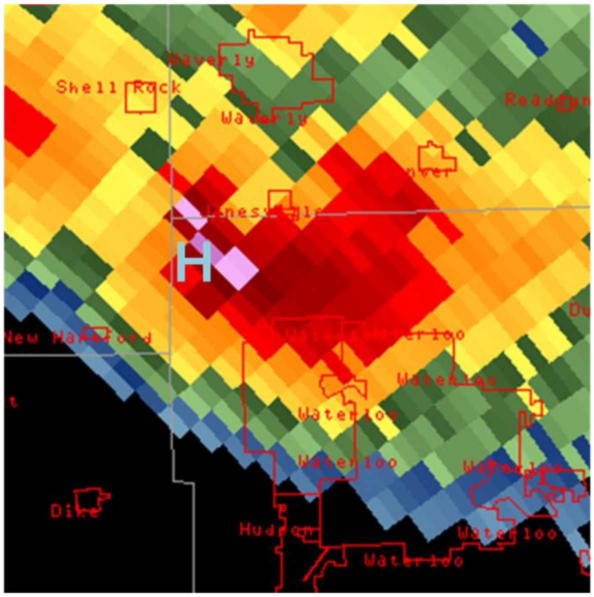


Fig. 7. 0.5 deg reflectivity and SRM 2208 UTC 25 May 2008, at the time a satellite tornado was reported on the ground near the Butler/Grundy county line (yellow T indicates position of tornado, Ts is satellite tornado)

At 2220 UTC, a television viewer reported softball size (4.25" diameter) hail in Finchford, in the far northwest portion of Black Hawk County (Fig. 8). The elevated storm core reached 67 dBZ at 32,000 ft AGL (above ground level).



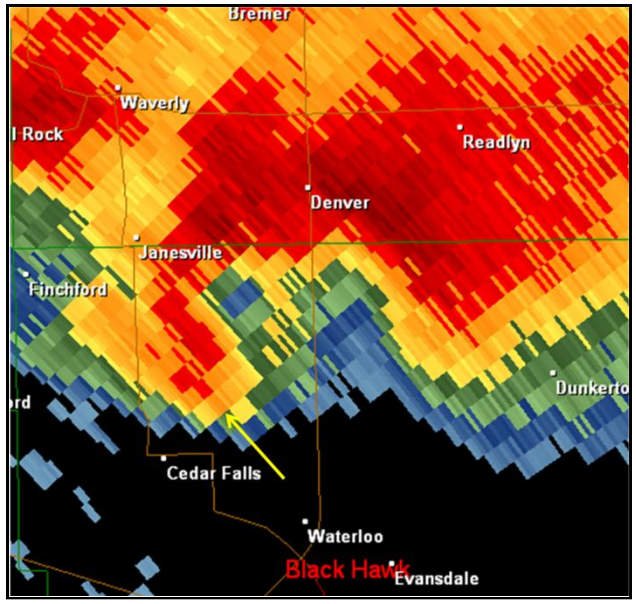


Fig. 8. 3.1 deg reflectivity 2217 UTC 25 May 2008 (cyan H indicates large hail location)

Fig. 9. 0.5 deg reflectivity 2231 UTC 25 May 2008 (yellow arrow indicates location of Waterloo Airport)

In addition to the large and destructive tornado, satellite tornado, and large hail, this storm produced very strong rear flank downdraft winds. At 2235 UTC, an 81 kt wind gust was recorded by the Automated Surface Observing System (ASOS) at the Waterloo Airport (Fig. 9). The tornado continued east across northern Black Hawk County and grew to near 1.2 miles wide north of Dunkerton, then dissipated just before entering Buchanan County.

Observations

- Meteorologists who worked in the days leading up to the Parkersburg tornado indicated that the Global Forecast System model (GFS) outperformed the North American Mesoscale model (NAM), and was consistent in advertising substantial instability and the potential for a significant severe weather event on the afternoon of 25 May 2008.

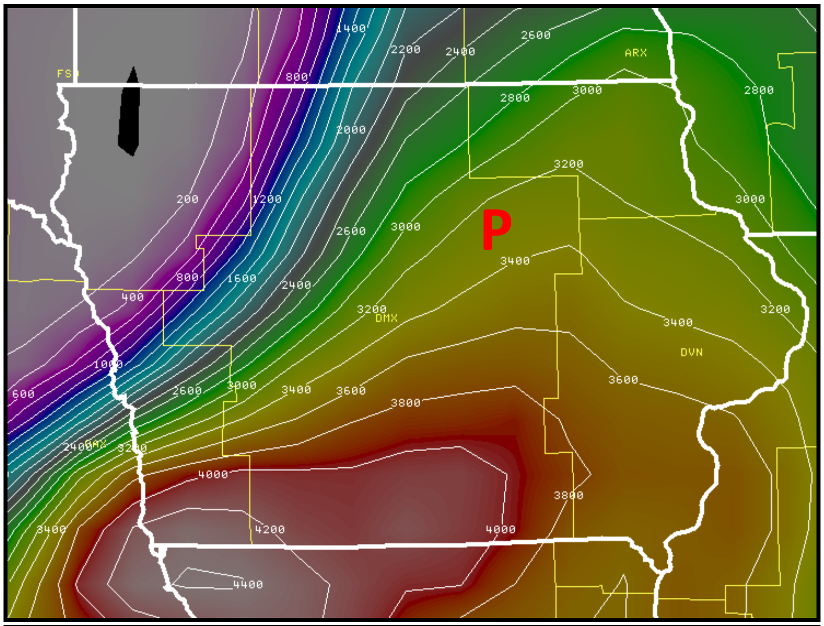


Fig. 10. 0000 UTC 25 May GFS ML CAPE forecast for 0000 UTC 26 May (red P indicates location of Parkersburg)

The evening before the event, the GFS was forecasting 3300 J/kg mixed-layer (ML) CAPE in the Parkersburg area (Fig. 10), while the NAM12 was indicating around 1500 J/kg (Fig. 11).

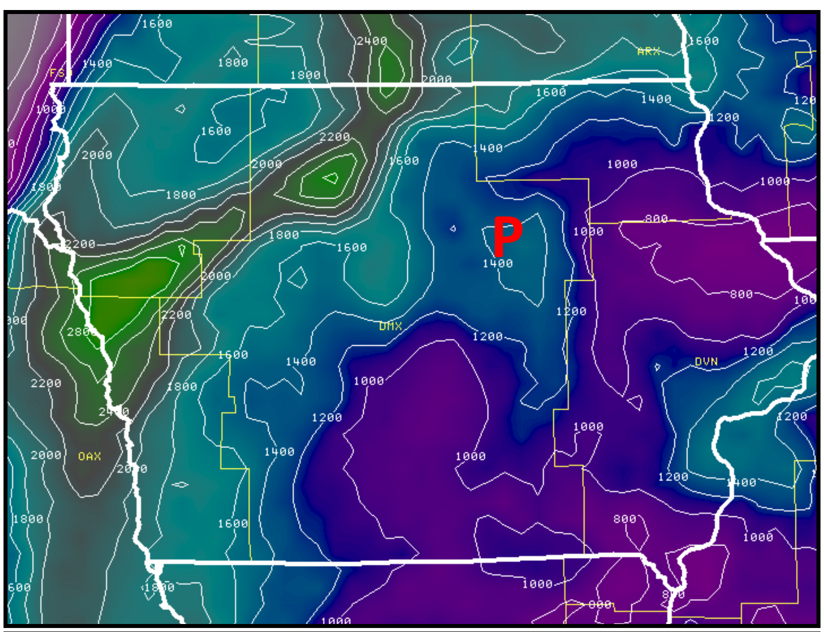


Fig. 11. 0000 UTC 25 May NAM12 ML CAPE forecast for 2100 UTC 25 May (red P indicates location of Parkersburg)

SPC mesoanalysis graphics showed nearly 3000 J/kg ML CAPE near Parkersburg at 2200 UTC on 25 May 2008 (Fig. 12). A comparison of forecast soundings near Parkersburg from the prior evening (Fig. 13) also illustrates the large difference in low-level heating and resultant CAPE.

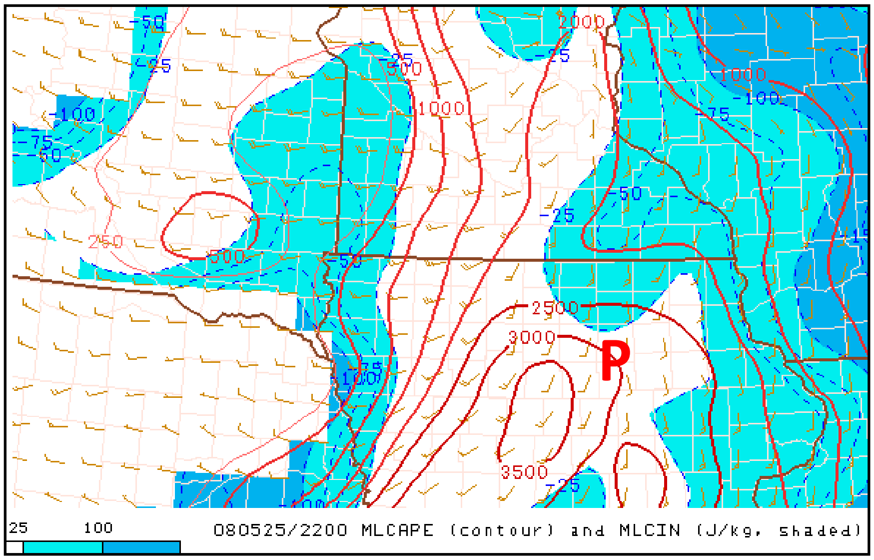


Fig. 12. 2200 UTC 25 May ML CAPE and ML CIN from SPC mesoanalysis graphics (red P indicates location of Parkersburg)

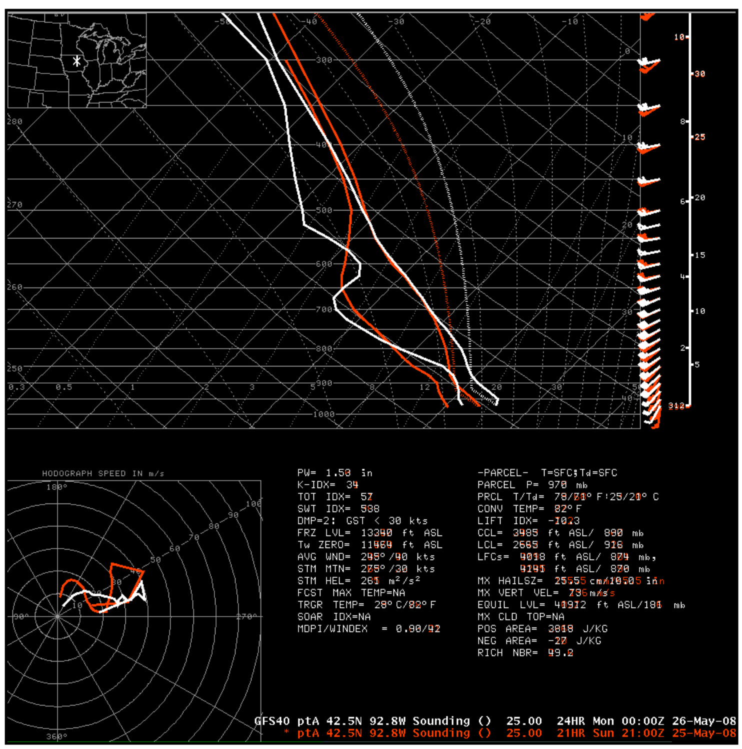


Fig. 13. 0000 UTC 25 May NAM/GFS forecast soundings valid for 2100 UTC 25 May/0000 UTC 26 May (NAM in orange and GFS in white)

Even as late as the 0600 UTC 25 May model run, the NAM12 was not developing any convection across the northeast portion of the DMX CWA through 0000 UTC 26 May, while the GFS remained consistent. Finally at 1200 UTC 25 May, the NAM12 and GFS, as well as the RUC, were all suggesting convection across northern Iowa during the afternoon, although the NAM12 continued to be much less unstable. This large difference in two of the primary models made it difficult for NWS meteorologists to go all out with a "high confidence" severe weather forecast in the days leading up to the event.

- Low-level mesoscale and near-storm environment parameters on 25 May 2008 were extremely favorable for tornadic supercell development, and were well recognized by the two warning teams.

Lingering cloud cover over northeast Iowa, and clearing to the west, helped enhance the baroclinic zone across the north-to-south-oriented warm front that was in place before convection developed (Fig. 14). Note the backed (southeasterly) surface flow near the secondary frontal boundary, favorable for enhancing low-level shear. Also of note is the character of the air mass just west of the warm front. Dew points of 70 degrees F or greater in the rear flank of the storm likely led to a relatively buoyant rear flank downdraft, which has been shown to enhance stretching of low-level vorticity contributing to tornadogenesis (Markowski et al. 2007).

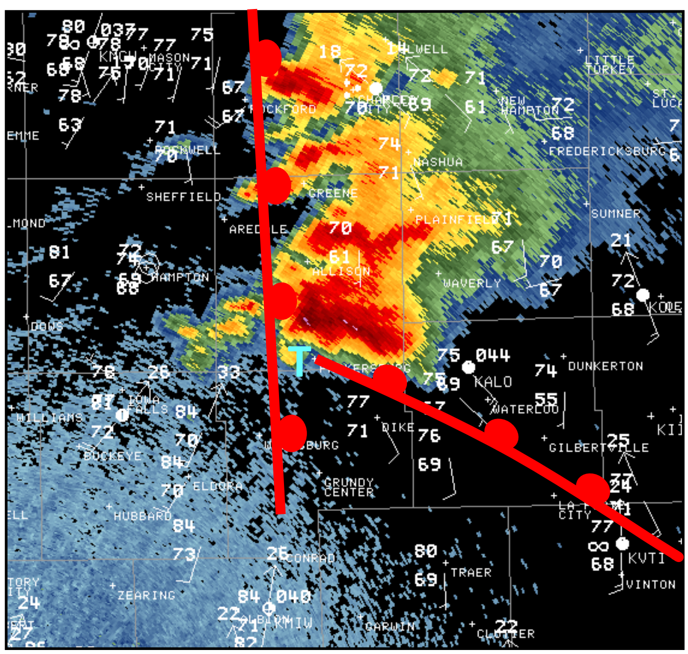


Fig. 14. 0.5 deg reflectivity, mesonet surface observations, and warm front locations at 2155 UTC 25 May 2008 (cyan T indicated position of tornado)

The SPC mesoanalysis page is a useful tool for warning forecasters during severe weather. Figs. 15 and 16 compare low-level parameters near Parkersburg derived from the SPC page at 2200 UTC on 25 May 2008, with local office guidance, and results from studies from Davies (2002) and Rasmussen (2003).

Low-level Tornado Parameter Summary*

22 UTC 25 May 2008

Parameter	SPC Mesoanalysis value	Tornadoes more likely
SRH 0-1 km	180 - 200 m2/s2	> 90 - 120 m2/s2
Bulk Shear 0-1 km	20 – 30 kt	> 16 – 20 kt
SRH 0-3 km	200 - 250 m2/s2	> 180 m2/s2
VGP 0-3 km	0.3 - 0.4	> 0.3
EHI 0-1 km	3 - 5	> 1.5
EHI 0-3 km	3 – 6	> 3
LCL	750 - 1000 m	< 1000 m
LFC	1400 - 1500m	< 1500 – 2000 m
SB CIN	25 - 50 J/kg	< 50 J/kg
0-3 KM CAPE	100 - 120 J/kg	> 60 – 90 J/kg

*office worksheet—values derived from numerous studies

Fig. 15. Near-storm environment values from SPC mesoanalysis page compared to local guidance

Mesoscale Parameter Summary

22 UTC 25 May 2008

Parameter	SPC Mesoanalysis value	Percentile value from Davies/Rassmussen studies
SRH 0-1 km	180 – 200 m2/s2	near 75th
SRH 0-3 km	200 - 250 m2/s2	near 60th
VGP 0-3 km	0.3 -0.4	60th to 75th
EHI 0-1 km	3-5	off the scale
LCL	750-1000 m	45th to 70th
LFC	1400-1500m	near 50th
SB CIN	25-50 J/kg	40th to 65th
0-3 KM CAPE	100 – 120 J/kg	50-60th

Fig. 16. Near storm environment values from SPC mesoanalysis page compared to studies from Davies (2002) and Rasmussen (2003)

Near-storm parameters were favorable across the board compared to local guidance. Compared to the Davies and Rasmussen studies, all but one parameter fell in the 40th to 75th percentile range for significant tornadoes. Feedback from the DMX SOO indicated that rarely are all parameters so favorable for tornadic supercells across the DMX county warning area. The warning teams discussed the mesoscale and near-storm environment and agreed that the threshold for issuing a tornado warning would be low.

- Forecast hodograph and sounding analysis indicated strong potential for tornadic supercells based on low-level "sickle" shape and other low-level parameters.

Miller (2006) and Esterheld et al. (2008) have shown the utility in diagnosing significant tornado days based on low-level hodograph characteristics. Specifically, Miller noted a "sickle" shape generally in the lowest 500 m AGL; with the average height of the hodograph kink around 400 m AGL. The RUC 1-hr forecast hodograph (Fig. 17) for Waterloo (23 miles east of Parkersburg) at the time of the tornado indicated a well-defined "sickle" shape and kink at 400 m AGL. Esterheld et al. also examined a number of significant tornado days, and noted a common characteristic in which the storm-relative inflow vector is orthogonal to the low-level (the portion below 400 m) straight line hodograph, (critical angle near 90 degrees) which would provide purely streamwise vorticity into the storm. Modifying this hodograph with actual surface observations (wind 140 at 14 kts at the Waterloo airport at 2200 UTC) and profiler data would yield a nearly straight line low-level hodograph and a critical angle near 90 degrees.

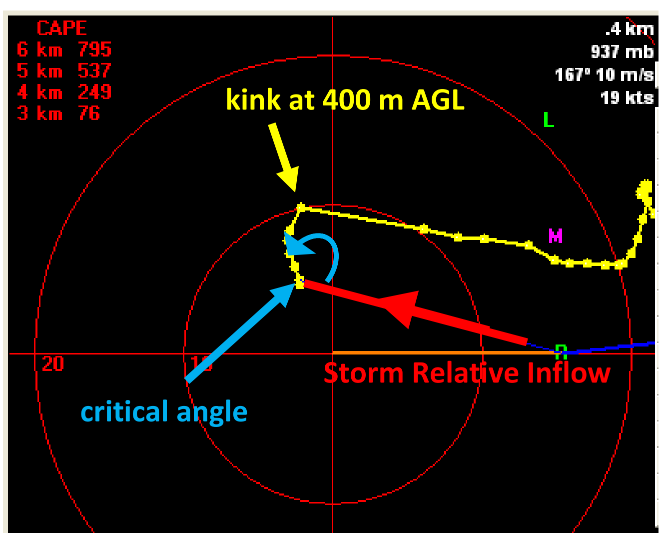


Fig. 17. 2100 UTC 25 May RUC forecast hodograph (valid for 2200 UTC 25 May at Waterloo)

Miller (2006) also cites an environment favorable for significant tornadoes as including decreasing mixing ratios in the lowest 1km AGL, a moderate to steep temperature lapse rate, and a surface mixing ratio of at least 15 g/kg. All of these conditions are met by the LAPS sounding (Fig. 18) valid at the time of the Parkersburg tornado.

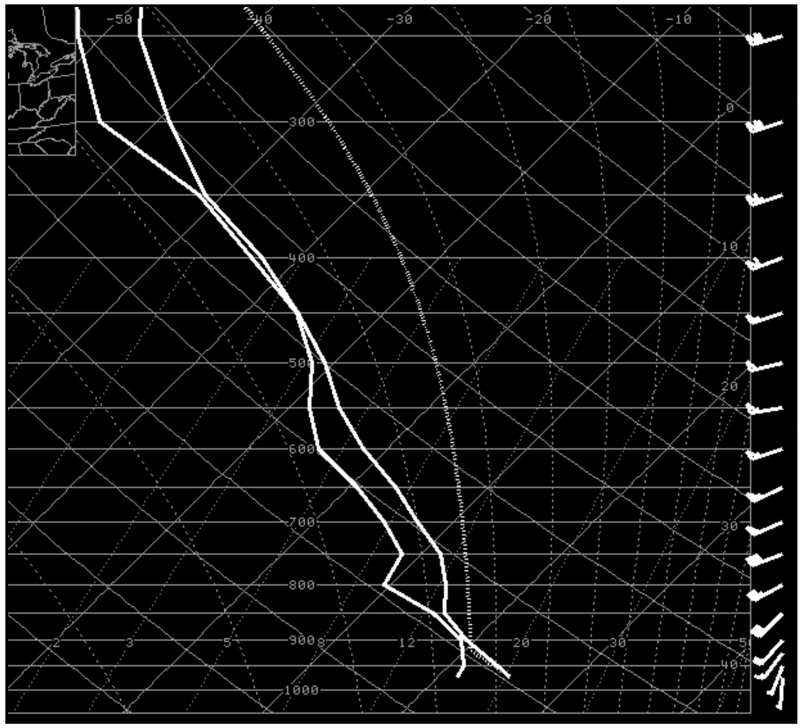


Fig. 18. 2200 UTC 25 May LAPS sounding for Parkersburg

- An examination of volumetric WSR-88D data for the 25 May 2008 event indicated evidence of a descending reflectivity core (DRC) prior to initial tornado formation.

Rasmussen et al. (2006) define a DRC as a blob-like area of precipitation that extends downward from the rear side of an echo overhang, and is located above a weak-echo region or bounded weak-echo region. Preliminary findings indicate tornado formation is often preceded by development of a DRC, but not always. Initial findings of Kennedy et al. (2007) also indicate the DRC is a better indicator of tornadogenesis than a hook echo or other appendage. The rear-flank DRC evident in Figs. 19 and 20 (indicated by gray arrow) was occurring about 7 to 11 minutes before the first spotter report of a tornado south of Aplington. The red arrow in Fig. 20 indicates the location of the DRC in plan view. Fig. 21 shows a more well-developed DRC as the tornado was nearing New Hartford, Iowa.

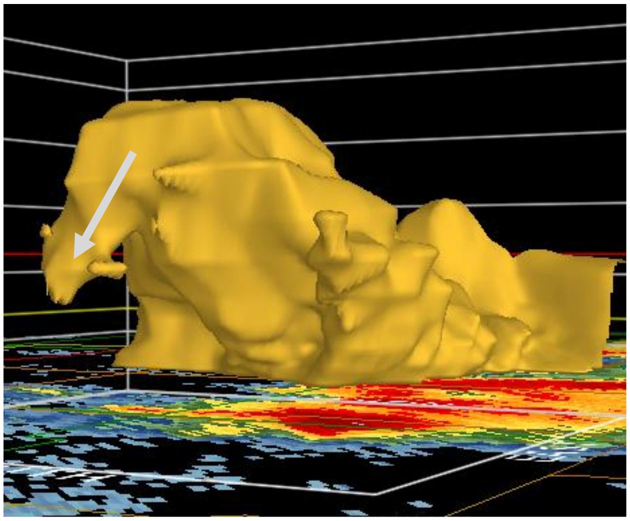


Fig. 19. Volumetric reflectivity, 2137 UTC 25 May 2008

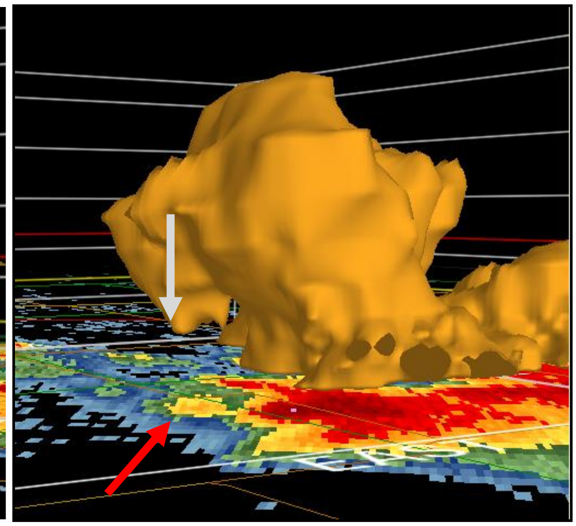


Fig. 20. Volumetric reflectivity, 2141 UTC 25 May 2008

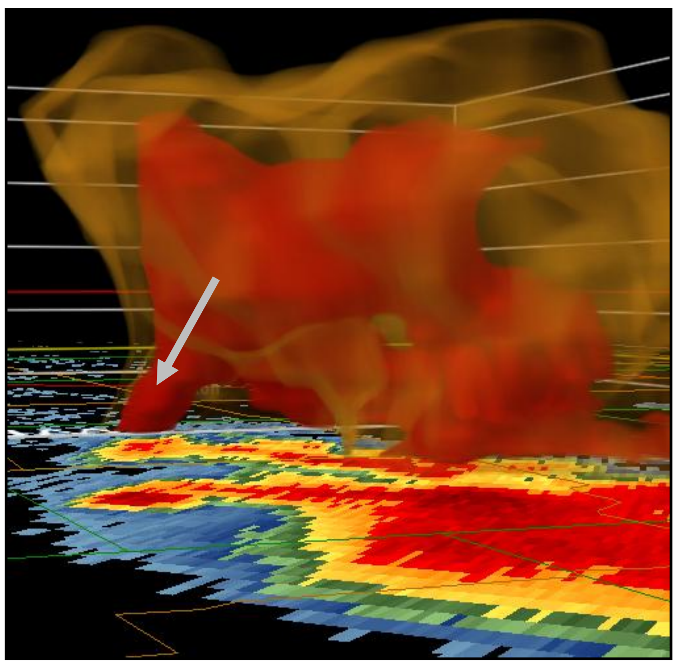


Fig. 21. Volumetric reflectivity, 2208 UTC 25 May 2008

Integrating real-time volumetric analysis into warning operations can be difficult, but should improve as volumetric data become available in the Advanced Weather Interactive Forecast Preparation System (AWIPS) Four-dimensional Stormcell Investigator (FSI) application. In this case, a DRC did precede tornadogenesis, and would have provided lead time. However, a proactive tornado warning had already been issued for the area at 2122 UTC.

- Gravity wave interactions may have contributed to the rapid intensification of the Parkersburg supercell.

Visible satellite imagery indicated an apparent gravity wave that initiated near Hastings and Hebron, Nebraska around 1500 UTC on 25 May 2008. This location is consistent with the synoptic patterns favorable for gravity waves outlined in Schaub (2005). The initiation region was just ahead of a cold front and in the right-rear quad of a 300-mb jet max. Koch and O'Handley (1997) developed a "duct factor", which is a measure of the duct strength in the stable layer, and the degree of conditional instability in the 700-mb to 400-mb layer. Values

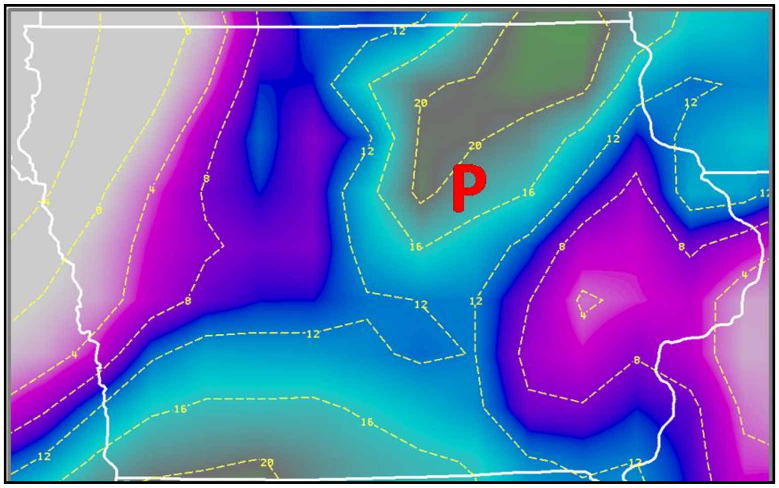


Fig. 22. RUC layer duct function in degrees C valid at 2200 UTC 25 May 2008 (red P indicates location of Parkersburg)

approached 20 degrees C near Parkersburg at 2200 UTC (Fig. 22); more than sufficient to support gravity wave development and propagation. A proximity sounding near Fort Dodge, Iowa at 1700 UTC (Fig. 23) also indicated a stable layer below 800 mb conducive for gravity waves.

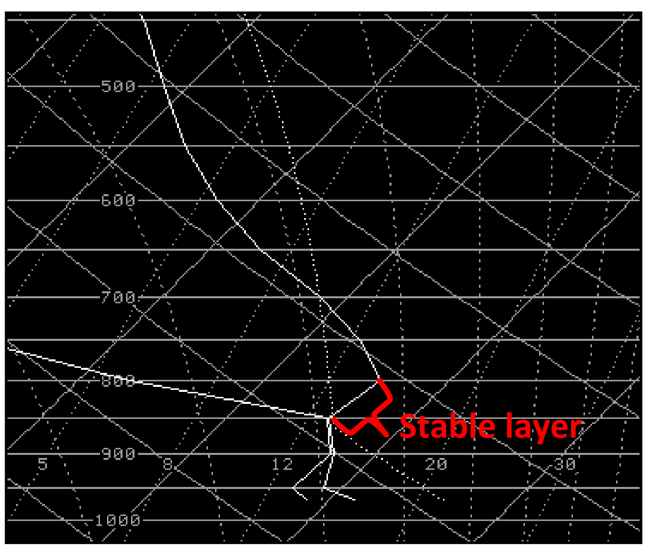


Fig. 23. RUC sounding at Fort Dodge, Iowa valid at 1700 UTC 25 May 2008

Storms fired just east of Fort Dodge around 2000 UTC, right after the second gravity wave moved through (Fig. 24), and near a pre-frontal trough.

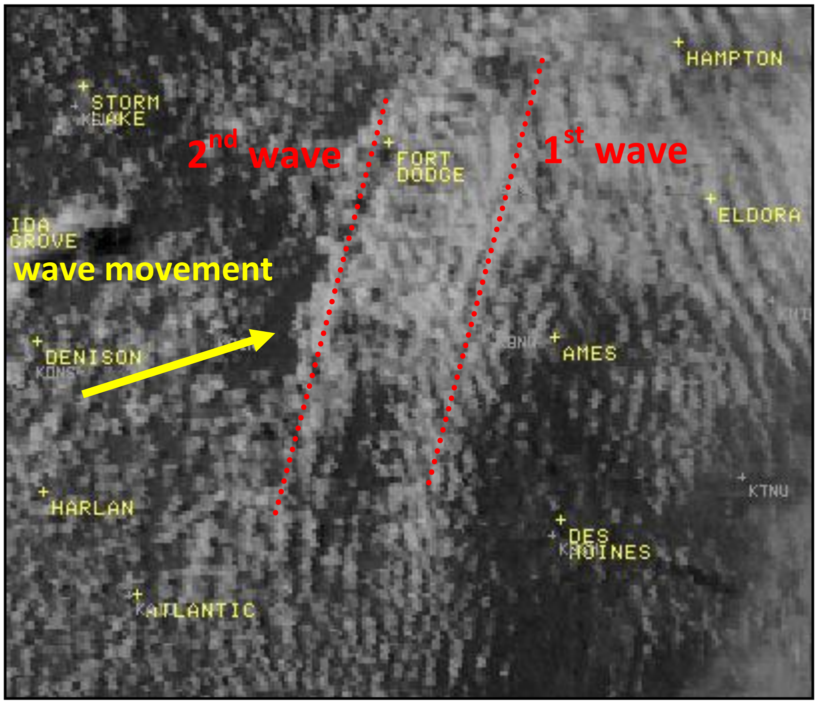


Fig. 24. Visible satellite imagery, 1955 UTC 25 May 2008 (gravity waves indicated by dashed red lines)

By 2140 UTC, just prior to tornado formation, the leading gravity wave had pushed east of the primary warm front, which extended north to south near the location of the first tornado (Fig. 25).

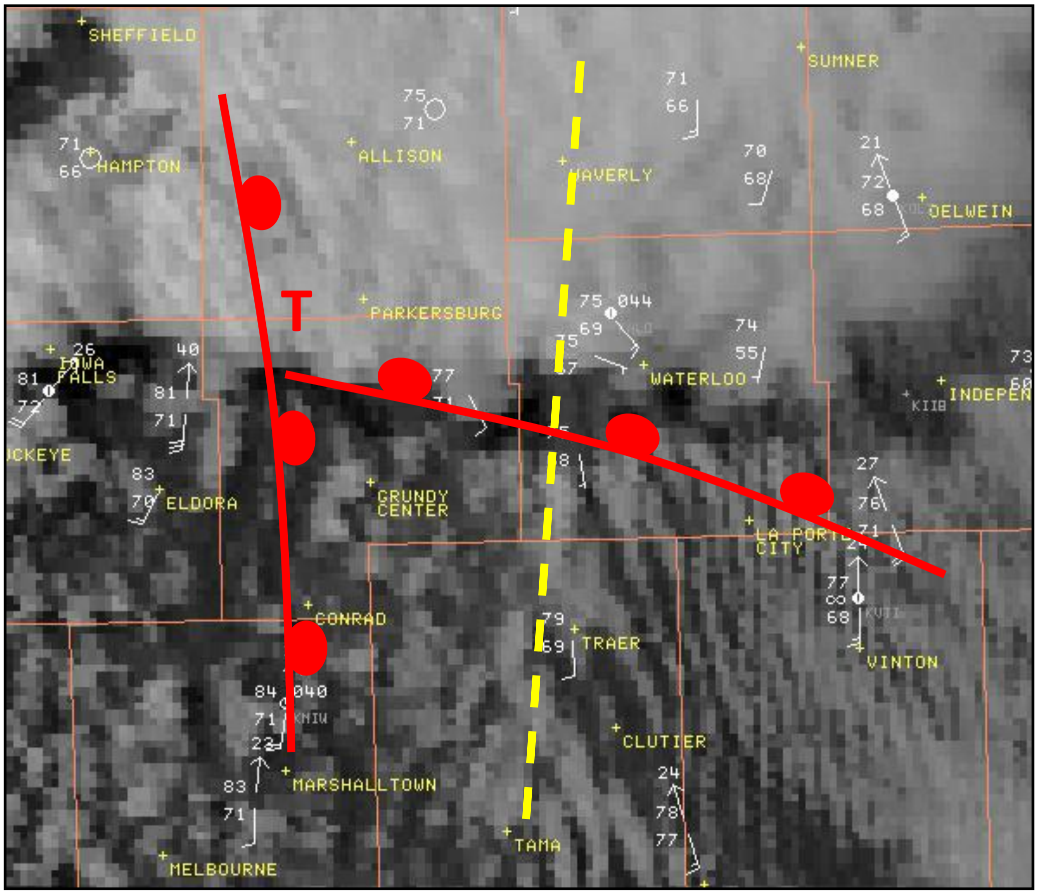


Fig. 25. Visible satellite imagery, 2140 UTC 25 May 2008 (yellow line indicates position of lead gravity wave, red T indicates location of initial tornado formation at 2148 UTC)

ASOS observations at the Waterloo Airport (KALO; below) indicate a familiar pattern associated with gravity waves, with surface pressure falls near the wave trough and pressure rises near the wave ridge (Schaub 2005).

SPECI KALO 252142Z 16011G18KT 5SM HZ BKN017 24/21 A2971 RMK AO2 LTG DSNT W-N PRESRR

METAR KALO 252154Z 14014KT 5SM VCTS HZ SCT019 BKN023 BKN028 24/21 A2967 RMK AO2 LTG DSNT SW-N TSB50 PRESFR SLP044 T02390206

The gravity wave was also visible briefly on a webcam located northwest of Tama, Iowa (Fig. 26).

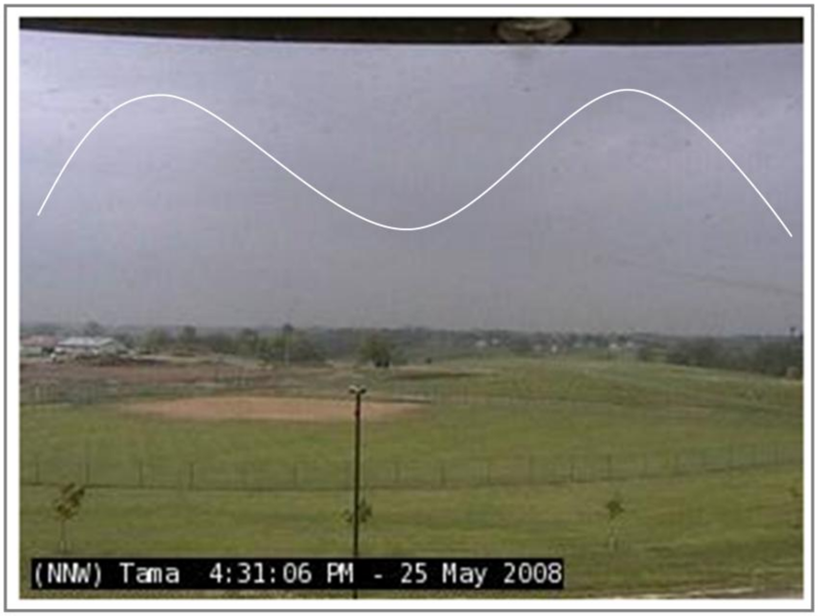


Fig. 26. Still image of clouds associated with gravity wave from Tama webcam, 2131 UTC 25 May 2008 (white line indicates position of wave ridges and trough)

While the lead gravity wave continued to hold together as it moved northeast of Parkersburg, the second wave had become imperceptible using base reflectivity and velocity data, and visible satellite imagery. However, an analysis of WSR-88D spectrum width data revealed that the second wave was still intact through the time when the first tornado developed (Fig. 27). Surrounding surface observations indicate this feature was not an outflow boundary, as there was no significant change in wind speed and direction, or temperature and dewpoint. The speed of propagation (around 50 kts) was also consistent with the lead gravity wave. The stable layer necessary for continued ducting of the gravity waves (Fig. 23) was elevated, and the gravity waves were likely elevated as well. This would explain why there were no substantial changes in surface observations as both waves moved through (with the exception of the rapid pressure rises and falls at the Waterloo Airport). The tornado developed just after the second wave (Fig. 27, dashed yellow line) passed. A nearly stationary fine line (Fig. 27, red solid line) likely indicates the position of the primary north-to-south oriented warm front. Coleman, et al. (2008) reviewed a number of cases in which gravity waves intersected with supercell thunderstorms, and presented evidence that a gravity wave can act to strengthen a mesocyclone in two ways: 1) wind convergence ahead of wave ridges causes enhanced stretching of vertical vorticity and 2) enhancement of streamwise horizontal vorticity in the storm inflow, which is then tilted into the vertical. Given the rapid mesocyclone intensification and tornado development shortly after the passage of both gravity waves, these processes may very well have acted to enhance the intensity of the Parkersburg supercell.

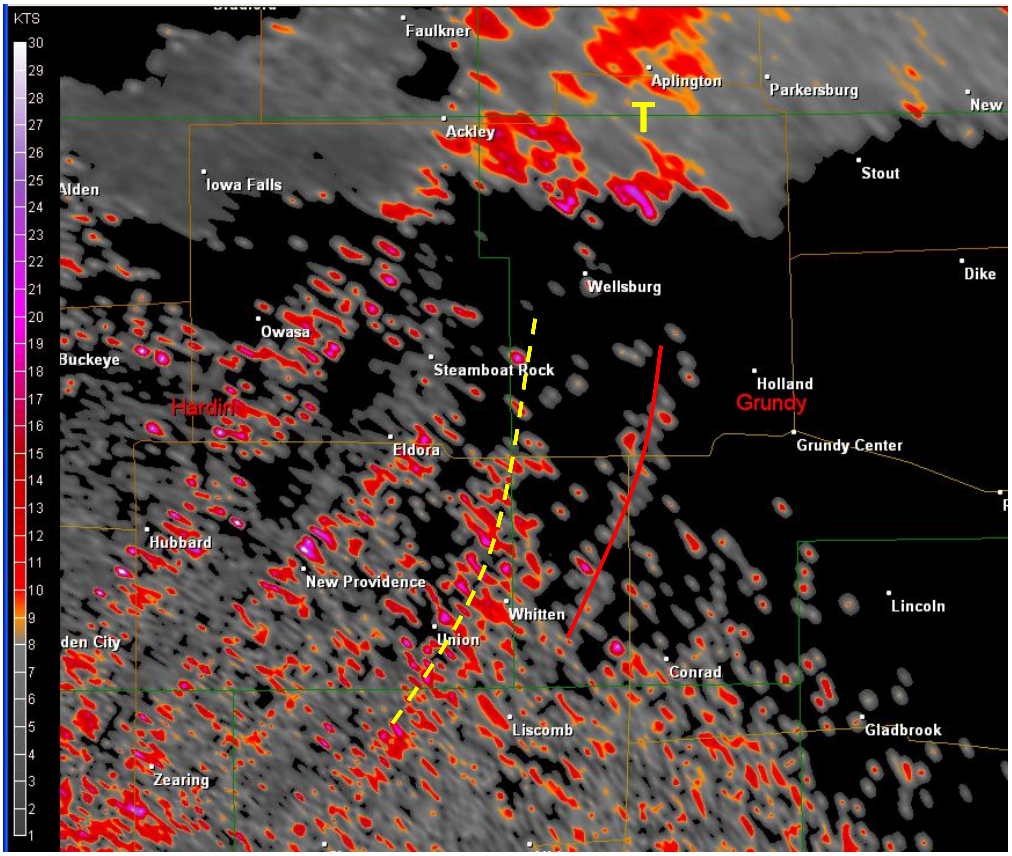


Fig. 27. 0.5 degree spectrum width 2141 UTC 25 May 2008 (dashed yellow line indicates location of second gravity wave, solid red line indicates possible mesoscale boundary, yellow T indicates location of initial tornado development at 2148 UTC)

- High-resolution WSR-88D radar data were very useful to warning meteorologists on 25 May 2008.

These data became available at WFO DMX on 14 May 2008, with the installation of ORPG/ORDA Build 10. Figures 28-29 below illustrate high-resolution and legacy examples of base reflectivity and storm-relative mean radial velocity (SRM). A sample of all-tilts SRM data revealed a developing mesocyclone with the strongest rotation at the 1.3 degree elevation (see Fig. 28a). Note the weaker and less organized circulation with legacy SRM data (see Fig. 28b). A comparison of hi-res and legacy reflectivity data also reveals much greater detail in the developing mid-level reflectivity core in the rear flank (see Figs 29a-b). A severe thunderstorm warning was in effect at 2118 UTC, and the warning forecaster upgraded to a tornado warning at 2122 UTC. This storm did not produce a tornado, but an early tornado warning was well justified given the very favorable environment and rapidly developing mesocyclone. Hi-res WSR-88D data appear to be a significant contributor to timely warnings, especially at greater distances from the radar. Iowa Falls is approximately 55 nautical miles from the KDMX Radar Data Acquisition unit (RDA) and the 1.3 degree elevation slice is about 10,000 ft AGL.

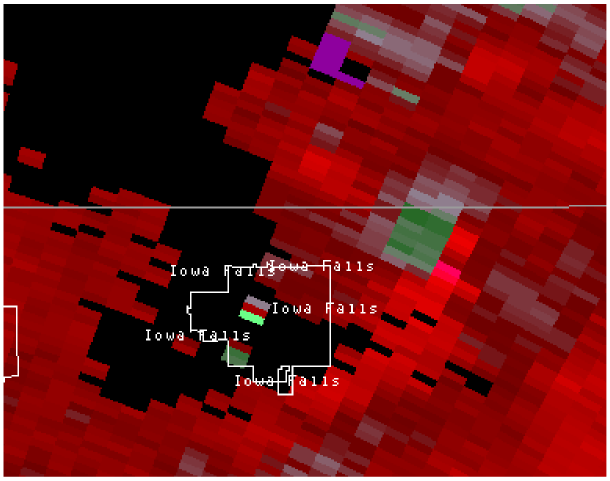


Fig. 28a. Hi-res 1.3 degree SRM 2118 UTC 25 May 2008

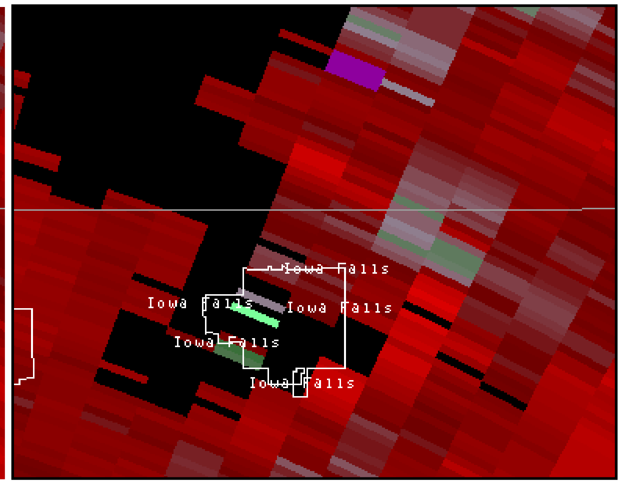


Fig. 28b. Legacy 1.3 degree SRM 2118 UTC 25 May 2008

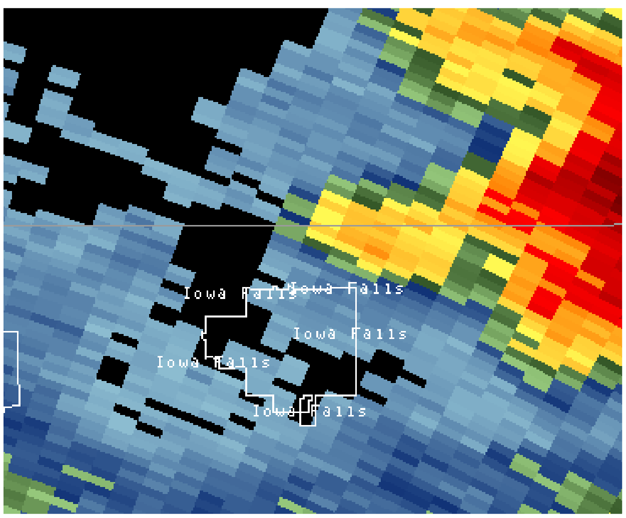


Fig. 29a. Hi-res 1.3 deg ref 2118 UTC 25 May 2008

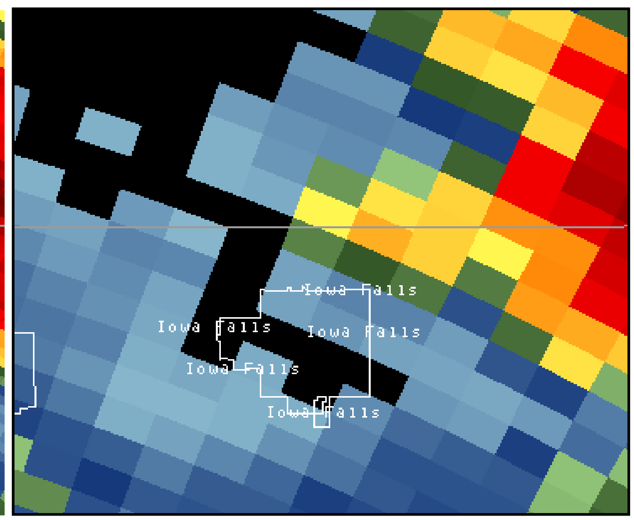


Fig. 29b. Legacy 1.3 deg ref 2118 UTC 25 May 2008

Hi-res SRM and base velocity data display a higher range of radial velocity values, and can give the warning forecaster a better idea of the strength of rotation. Fig. 30a indicates an inbound velocity max of 118 kts (purple) and an outbound max of 79 kts (orange). The maximum gate-to-gate shear (indicated by the yellow circle) was 93 kts. Legacy SRM data in Fig. 30b indicate an inbound velocity max of 84 kts (cyan) and an outbound max of 69 kts (bright pink). The maximum gate-to-gate shear (indicated by the yellow circle) was 57 kts.

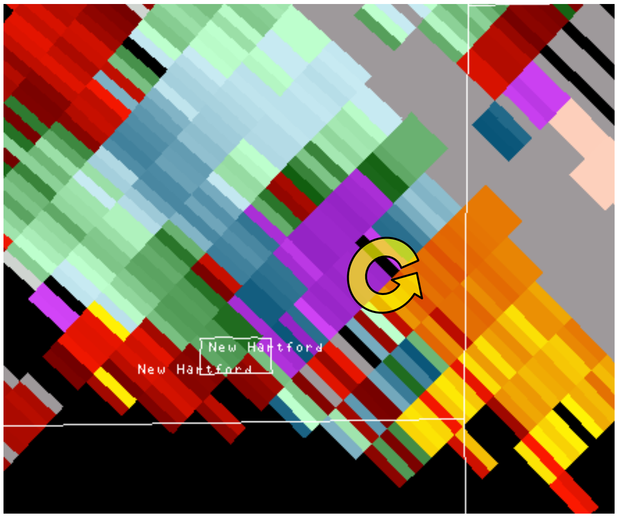


Fig. 30a. Hi-res 0.5 deg SRM 2213 UTC 25 May 2008

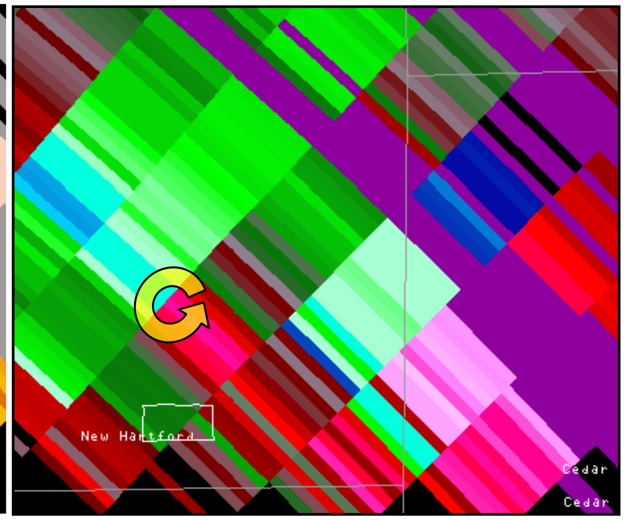


Fig. 30b . Legacy 0.5 deg SRM 2213 UTC 25 May 2008

Acknowledgments

The authors wish to thank the WFO Des Moines management and meteorologist staff for providing valuable meteorological insight into this event and for comments in review of this manuscript.

References

Coleman T.A., Knupp K.R., 2008: The Interactions of Gravity Waves with Mesocyclones: Preliminary Observations and Theory. *Monthly Weather Review*: In Press

Davies, J.M., 2002: On low-level thermodynamic parameters associated with tornadic and non-tornadic supercells. Preprints, *21st Conf. on Severe Local Storms,* San Antonio, TX, Amer. Meteor. Soc., 603-606.

Esterheld, J.; Giuliano, D.. Discriminating between Tornadic and Non-Tornadic Supercells: A New Hodograph Technique. **E-Journal of Severe Storms Meteorology**, North America, 3 7 07 2008.

Kennedy, A., J.M. Straka, and E.N. Rasmussen, 2007: A Statistical Study of the Association of DRCs with Supercells and Tornadoes. *Wea. Forecasting*, **22**, 1191–1199.

Koch, S. E., and C. O'Handley, 1997: Operational forecasting and detection of mesoscale gravity waves. *Wea. Forecasting,* **12**, 253-281.

Markowski, P.M., J.M. Straka, and E.N. Rasmussen, 2002: Direct Surface Thermodynamic Observations within the Rear-Flank Downdrafts of Nontornadic and Tornadic Supercells. *Mon. Wea. Rev.*, **130**, 1692–1721.

Miller, D. J., 2006: Observations of low level thermodynamic and wind shear profiles on significant tornado days. Preprints, *23rd Conf. on Severe Local Storms,* St. Louis, MO, Amer. Meteor. Soc., 1206-1223.

Rasmussen, E.N., 2003: Refined supercell and tornado forecast parameters. *Wea. Forecasting,* **18**, 530–535.

Rasmussen, E.N., J. M. Straka, M. S. Gilmore, and R. Davies-Jones, 2006: A survey of the occurrence of rear-flank descending reflectivity cores in a sample of supercells. *Wea. Forecasting*, **21**, 923-938.

Schaub, Jr., W.R.: Gravity Waves: Those Important to Operational Weather Forecasting. Forecasting Note, 28 February, 2005.

EF Scale

Enhanced Fujita (EF) Tornado Scale

The Enhanced F-scale, also known as the EF scale, is a set of wind estimates (not measurements) based on damage. It uses three-second gusts estimated at the point of damage based on a judgment of different levels of damage. Levels of damage are judged based on 28 damage indicators. These estimates vary with height and exposure. The 3 second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures using a directly measured "one minute mile" speed.

Operational EF Scale	
EF Number	3 Second Gust (mph)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200