Meteorology, climatology, and the communication and interpretation of weather information during the 22 May 2008 Weld County, Colorado tornado

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Weld County Tornado: 22 May 2008

- 34-mile track through northern Colorado; moved toward the northwest at ~30 mph
- Formed early in the day: storm developed around 1100 MDT, first tornado report at 1126
- Most serious impacts were on the west side of the city of Greeley and the eastern half of the town of Windsor
- Rated 3 on the Enhanced Fujita scale
- One fatality at a campground in Greeley
- Over 800 homes damaged and 80 destroyed in Windsor
- $193M in insurance claims, costliest tornado in CO history (Denver Post)
Questions to answer

- What were the meteorological conditions that were conducive to significant tornadoes on 22 May 2008?
- How rare was this event?
  - Northwestward motion
  - Location so near the Front Range
  - Time of day
- How was severe weather information communicated and interpreted in an area relatively unaccustomed to significant tornadoes?

Photos courtesy of National Weather Service Boulder
Overview of meteorological conditions

- Large-scale forcing for ascent provided by deep, negatively-tilted trough in the western US
- Jet streaks moving through the upper-level flow; one was located over eastern Colorado
- Surface low-pressure center just east of Denver
- Strong easterly winds advecting moisture into northern Colorado on the north side of this low
National Weather Service Forecasts

From the Storm Prediction Center’s 1630 UTC (10:30 am) Convective Outlook:

SURFACE BASED STORMS ARE LIKELY TO DEVELOP ACROSS NERN CO...ESPECIALLY ALONG AND NORTH OF THE PALMER RIDGE BY EARLY AFTERNOON. ONCE STORMS FORM...THE AMOUNT OF INSTABILITY AND EFFECTIVE SHEAR AT 60 KT WILL RESULT IN RAPID SUPERCELL DEVELOPMENT. THERMODYNAMIC PROFILES SUGGEST VERY LARGE HAIL WILL BE THE MAIN THREAT...THOUGH SRH VALUES FROM 200-300 M2/S2 FAVOR TORNADOES...SOME STRONG.

- First storms: 1645 UTC (10:45 am local time)
- First Severe Thunderstorm Warning: 11:09 am
- First Tornado Warning: 11:18 am
- A Tornado Watch was then issued by SPC at 11:25 am for northeastern Colorado
- The first tornado was reported east of Gilcrest at 11:26 am
- Tornado hit Windsor just before noon
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Photos courtesy of National Weather Service Boulder
F2+ Tornadoes in Weld County

- Western Weld County has been hit numerous times, but the most recent (before 2008) were in 1952 and 1957.
- Last significant tornado anywhere in Weld County was in 1996; since then, the population of this area has grown rapidly, suggesting that most residents have not experienced a damaging tornado in this area.
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Photos courtesy of National Weather Service Boulder
Method: Semi-structured interviews

- Semi-structured interviews of decision makers in the tornado-warned areas

- Breakdown of interviewees:
  - 3 emergency managers
  - 5 school administrators
  - 4 university officials
  - 2 school teachers
  - 1 small business manager
  - 1 broadcast meteorologist

- Not a representative sample, instead designed to get diversity of points of view
Topics for interview questions

- Initial sources of information; interpretation; barriers to receiving information
- Subsequent sources of information; interpretation; barriers
- Past experience with tornadoes and how it related to this event
- Usefulness of information; additional information sources that would have been helpful/useful
Sources of information

- Multiple sources of initial information (consistent with past work, e.g., Hammer and Schmidlin 2002)
  - Emergency managers heard of warnings from dispatch
  - Media
  - Word of mouth
  - Proprietary software

- NOAA weather radio (NWR) was not used for initial information by our interviewees

- Some problems arose because of power outages and cell phone outages
  - NWR was then used later in the day

- Emphasizes need for multiple, redundant methods
Lead time

Adapted from Pingel et al. (2005) to tornado situation
Past studies have identified a sequence of processes that describe people’s responses to warnings (e.g., Mileti and Sorenson 1990; Sorenson 2000):

- Hearing the warning
- Understanding the contents of the warning
- Believing the warning to be credible
- Personalizing the warning to oneself
- Confirming the warning is true and others are taking heed
- Responding by taking protective action
Lead time

- Lead time varied among interviewees
  - Some received the very first warnings
  - Others didn’t hear a warning until the storm was very close to them

- Actual reports were key
  - Actual tornado reports (rather than just the warning) are what made the interviewees realize there was a serious risk of a tornado in their area
  - Some would have liked even more specific information about the location of the storm
  - Those downstream had more time to hear previous reports and damage information
  - Similar to finding/recommendation in NWS assessment report for Super Tuesday outbreak
Two contrasting stories

- Two officials who received warning at the same time:
  - “A tornado is on the ground in Gilcrest”
  - One also heard that the storm was moving **north**; realized that this was toward their area
    - Relatively long action/mitigation time
  - Another assumed that because tornadoes generally move to the east that their area was not in danger. Didn’t hear another warning until 2-3 minutes before the tornado hit
    - Understanding and personalizing steps were long, action/mitigation time was short
Contrasting stories

a) Data collection and evaluation (performed elsewhere)  Notification and decision making  Action (mitigation) time

- Storm initiates
- Warning received
- Warning understood and threat personalized; Response begins
- Tornado hits

b) Data collection and evaluation (performed elsewhere)  Notification and decision making  Action (mitigation) time

- Storm initiates
- Initial warning received
- Initial warning not understood or personalized
- Later warning received and understood; threat personalized; Response begins
- Tornado hits
More questions than answers

- The small sample size, and qualitative nature of this study can’t provide any definitive answers, but it does re-emphasize many ongoing questions regarding warning communication and behavior:
  - How to bridge the divide between the information that meteorologists have and how it is used? Is there a way (and should there even be a way) to encourage people to respond based on a warning alone, without a confirmed tornado?
  - How can the research and operational meteorology community use the knowledge that most people do not respond immediately and directly to tornado warnings—instead, they go through a sequence of thought processes—to encourage the desired response to a warning?
  - How to communicate the most important message in warnings: “the storm is moving to the north”; “this is more serious than most storms in this area”, etc.
Summary and conclusions

- We conducted an integrated meteorological, climatological, and societal analysis of the 22 May 2008 Weld County, Colorado tornado.
- A variety of societal factors determined how decision makers received and interpreted severe weather information and how they responded to the threat.
- The sequence of processes by which the decision makers processed information was consistent with past social science research on warning communication.
- The meteorological and climatological context for this event had a relationship to the societal aspects, suggesting there is value to integrated studies such as this, in addition to efforts to improve detection and prediction.
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More information:
http://rammb.cira.colostate.edu/case_studies/20080522/
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