False Alarms, Close Calls, and Tornado Warning Verification Records

by Kevin M. Simmons* and Daniel Sutter**

The National Weather Service (NWS) issued tornado warnings by county until switching to storm-based warnings in 2007. A warning verified when a tornado occurred in the county during the warning period. The false alarm ratio (FAR) is the number of warnings that fail to verify divided by the total number of warnings issued, and is a NWS performance metric. Between 1986 and 2004, the nationwide FAR for tornado warnings was 0.758, so three out of four warnings issued failed to verify. Clearly, a high FAR threatens the credibility of hazard warnings (Breznitz 1984).

Researchers have noted several limitations in the definition of false alarms: a tornado could occur just after a warning expires or just a few hundred yards out of the warning area, or could dissipate just before crossing a county line. Warnings in all these instances are by definition false alarms, and yet may not undermine public confidence in the credibility of warnings. Barnes et al. (2007) suggest adding a conceptual category of a “close call” to our thinking about hazard warnings and recommend “an improved performance measure that calculates close calls differently than false alarms. A close-call performance measure would give credit to forecasters for the many times close calls occur, rather than becoming part of the high FAR”.

The Barnes et al. criticisms imply that because of the many definitional false alarms that are really close calls, the tabulated NWS FAR may not be useful for hazards researchers looking to investigate, say, a false alarm effect (Dow and Cutter 1998). We explore the effect of close calls by defining an alternative false alarm ratio using NWS verification statistics that takes some of these criticisms into account. The alternative definition could result in the NWS FAR being uncorrelated with public perceptions of warning credibility, and slicing the data differently may yield a measure closer to the unobserved true perceptions. At a minimum, the alternative definition allows us to see how significant the problem of close calls may be.

NWS verification records do not allow us to identify all close calls. For example, the records do not indicate when, say, a severe thunderstorm produced a wall cloud that nearly touched down. But some of the concerns discussed by Barnes et al. can be addressed. We calculated a FAR using the state warning day instead of the county warning as the unit of observation. A state warning day is any calendar day on which a tornado warning was issued anywhere in a state. The state warning day verifies that a tornado occurred anywhere in the state on this day; it does not verify that no tornado occurred in the state on this day. The state warning day FAR is the number of state warning days that fail to verify divided by the number of state warning days.

State warning days eliminate some close calls. For instance, if a tornado strikes one of four warned counties in the path of a super cell thunderstorm, the NWS FAR for the event would be 0.75, but this would be a verified state warning day with a state warning day FAR of 0. We also control for most tornadoes occurring just after or outside the warning. The intuition behind the state warning day is that residents might remember if tornado warnings were issued on a day and if tornadoes occurred that day, but not the exact time and location of the tornadoes and warnings.

For instance, a resident might see warnings reported on TV and then news stories if a tornado occurred. Our state warning day definition probably rules out some events that would not count as a close call; tornadoes could occur 100 or more miles away or hours before or after a warning and still result in a verified state warning day. And in other cases, a tornado might occur just across a state line or after midnight and be counted as a false alarm. Our state day definition is far from perfect, but it does suggest a way to account for some close calls. And importantly, it allows us to divide the available records differently, to explore if controlling for close calls substantially affects the FAR.

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Table 1 illustrates our measure for Alabama in 1986. Forty county warnings were issued in Alabama in 1986 on eight different days, so there were eight state warning days. The table has one row for each warning day, and also reports for each day the number of warnings issued, the number of tornadoes in Alabama, the number of verified county warnings, and whether the state warning day verified. Three of the state warning days verified, so the state warning day FAR was 0.625 for the year, and the FAR for county warnings for Alabama in 1986 was 0.8.

<table>
<thead>
<tr>
<th>Date</th>
<th># of tornado warnings</th>
<th># of tornadoes</th>
<th># of verified warnings</th>
<th>Verified state warning day</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>February 10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>March 12</td>
<td>27</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>May 18</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>May 24</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>June 18</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>August 10</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>November 26</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>40</td>
<td>9</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

NWS FAR = 0.800 = 32/40. State Warning FAR = 0.625 = 5/8.

We explored the relationship between the state day FAR and the NWS FAR over time and across states. Figure 1 graphs the national NWS FAR and state warning day FAR by year from 1986 to 2004. The state day FAR is less than the county warning FAR in each year, as we would expect, and the two measures move together; the correlation between the annual FARs is +0.57. But the measures are not perfectly correlated.

Suppose we wanted to test for a change in the FAR over this period. A regression of the FAR on a constant and a linear time trend yields a reduction of 0.04 over the period with the NWS FAR, which suggests a modest improvement in false alarms and credibility. But the same regression using the state warning day FAR indicates an increase of 0.04 over the period. Neither time trend attains significance at conventional levels, but the difference in results suggests that the observed decline in the NWS FAR might be caused by fewer definitional false alarms with little gain in credibility.

The nationwide state warning day FAR between 1986 to 2004 was 0.420, and the county warning FAR was 0.758. Not surprisingly, the FAR falls when some close calls are reclassified. Yet even with our rather generous state warning day definition, false alarms do not vanish. Also, unwarned events still occur; over these 19 years, tornadoes occurred on 2,389 days on which no warnings were issued in the state.

The real value of an alternative definition of a FAR arises from comparison with the NWS FAR. That the NWS FAR deviates from the “true” FAR if we could exclude all close calls does not render the NWS FAR useless for research. The pattern of deviation is what is really important. Suppose that the “true” FAR excluding all close calls was always exactly half of the NWS FAR. Since the NWS FAR in this case perfectly tracks the true FAR, hazards researchers could still use the NWS FAR to, for example, try to document a cry wolf effect.

Figure 2 plots the state warning day FAR and NWS FAR for each state from 1986 to 2004. The plot shows an approximate linear relationship between the FARs, as would be the case if the state warning day FAR were proportional to the NWS FAR. The correlation between the FARs is +0.61, slightly greater than the correlation over time. The NWS FAR captures the risk across states fairly well, but again the FARs are not perfectly correlated. California and Utah, for example, have two of the highest NWS FARs and yet very low state warning day FARs; South Carolina has a relatively high state warning day FAR but the second lowest NWS FAR. The biggest deviations in the FARs, however,
do tend to occur in states with relatively few tornado days.

**Conclusion**
The NWS undoubtedly counts as false alarms many cases where a tornado warning alerts residents to danger. The national tornado FAR of about 0.75 suggests that warnings are possibly less credible than they in fact are for residents. But how big is the divergence between the reported FAR and the credibility of warnings? To offer some perspective, we constructed an alternative measure of false alarms using NWS verification statistics. Differences in the state warning day FAR track the NWS FAR reasonably well, so the NWS FAR probably measures differences in the credibility of tornado warnings across the country fairly well. But the modest reduction in the yearly FAR observed over 20 years might be more definitional than real.

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References


**Figure 2: False Alarm Ratios by State**

![Figure 2: False Alarm Ratios by State](image)