An Analysis of Total Lightning Over North Alabama During the 2 March 2012 Tornado Event

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I. Background

North Alabama Lightning Mapping Array (NALMA)

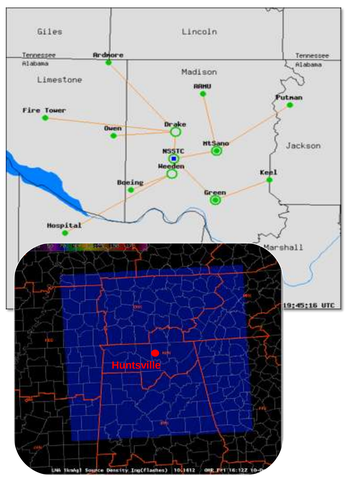


Figure 1a, 1b: (a, top) Sensors within the North Alabama LMA during peak operation; closed green circles denote array sensors; open green circles denote communications relays; the blue square denotes the National Space Science and Technology Center (main processing center for the array); (b, bottom) NALMA effective domain under most conditions (though coverage was diminished on 2 March).

- Created in 2001, data transitioned to NWS HUN in 2003
- Provides *total* lightning
  - Cloud-to-ground *and* intra-cloud lightning
- NALMA sources are strongly related to storm updraft strength
- Available within NWS AWIPS-1, nearly ready for AWIPS-2
- Two minute temporal resolution
- Proxy for Geostationary Lightning Mapper (GLM) on GOES-R
- On 2 March, operating at diminished capacity due to damage from 27 April 2011

2 March 2012 Outbreak

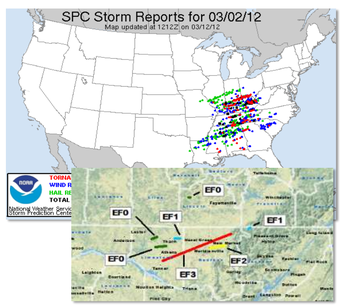


Figure 2a, 2b: (a, top) Storm Prediction Center storm reports map for 1200 UTC 2 March 2012 to 1200 UTC 3 March 2012; (b, bottom) Zoomed-in view of the tornado tracks in the NWS Huntsville County Warning Area.

- Severe weather, including two significant tornadoes, began around 9 AM CST in northern Alabama
- Overall, 41 reports of severe weather in the Huntsville CWA
  - Reports of softball and baseball size hail
- 7 tornadoes in the Huntsville CWA
  - 1 EF-3 (morning)
  - 1 EF-2 (morning)
  - 2 EF-1s
  - 3 EF-0s

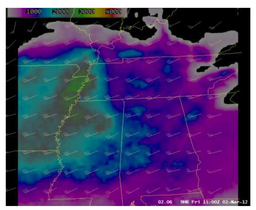


Figure 3: 12 km RUC depiction of SBCAPE at 1500 UTC 2 March, via NWS AWIPS.

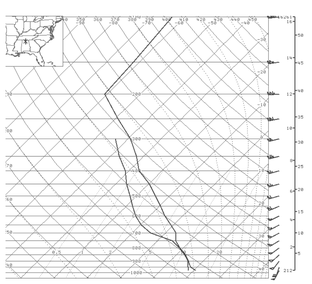


Figure 4: RUC proximity sounding valid 1600 UTC 2 March at KHSV. Surface-Based CAPE is indicated as 1841 J kg^{-1} and 0-3km Storm-Relative Helicity is 508 m^2 s^{-2}.

II. NALMA Data as a Warning Decision Support Tool

- NALMA data were used to augment radar imagery from Hytop, Alabama (KHTX) to initiate severe thunderstorm warnings on the morning of 2 March 2012, initially for severe hail
- Radar reflectivity was not initially supportive of severe hail, but indicated a marginally severe storm.
- NALMA source density indicated a lightning "jump" (greater than 2σ as suggested by Schultz et. al. 2009) between 1442 and 1446 UTC, indicating a rapidly-strengthening updraft
- First severe thunderstorm warning of the day was issued at 1451 UTC

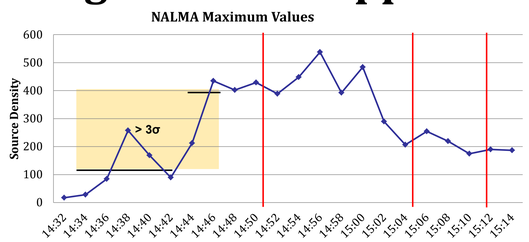
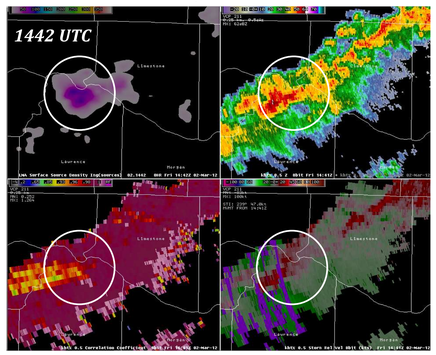
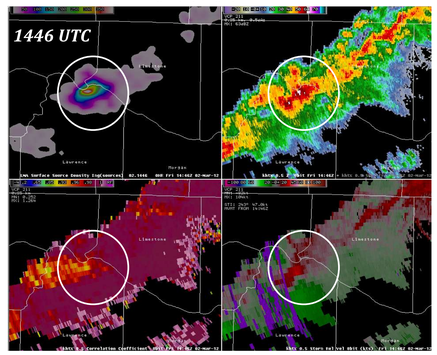


Figure 5: Time series of maximum NALMA source density values associated with the first storm on 2 March 2012. The highlighted area marks a lightning "jump"—an increase of greater than 3 standard deviations (though the severe weather often occurs after the corresponding fall-off as the core descends). The red lines mark three significant points:

- 14:51 – First severe weather warning issued
- 15:05 – First severe weather report, 1" hail
- 15:12 – Report of 4.45 cm (1.75 in) hail and 31 m s^{-1} (70 MPH) winds

Figure 6a, 6b: (a, left) An AWIPS-1 (Advanced Warning Interactive Processing System) display from 1441 UTC (radar) and 1442 UTC (LMA) . Clockwise from top-left: NALMA source density, KHTX reflectivity, KHTX storm-relative velocity, and KHTX correlation coefficient (ρhv). (b, right) The same as in 4a, but for 1446 UTC.





III. Morning Significant Tornadoes

EF-3 Tornado: 1510 to 1600 UTC

- As noted above, NALMA data indicated a lightning jump from 1442 to 1446 UTC, and a corresponding decrease occurred from 1500 to 1504 UTC
- First tornado of the 2 March 2012 event touched down at 1510 UTC in eastern Athens, Alabama, remained on the ground for 34 miles and reached a wind speed of 140 MPH, resulting in an EF-3 rating
- Peak intensity occurred as a secondary updraft was peaking and approximately 6 minutes after the primary updraft reached a peak

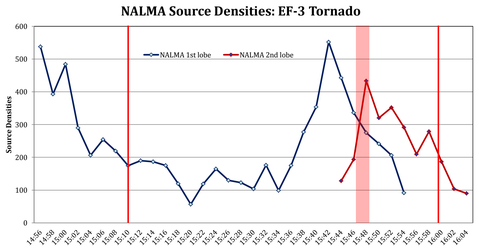


Figure 7 *(above)*: Time series of maximum NALMA source density values associated with the first tornado on 2 March 2012. The red lines mark three significant points: 1510 UTC, when the tornado touched down; approximately 1548 UTC, when the tornado reached a peak intensity of EF-3 on the Enhanced Fujita Scale; and 1600 UTC, when the tornado lifted in northeastern Madison County, AL.

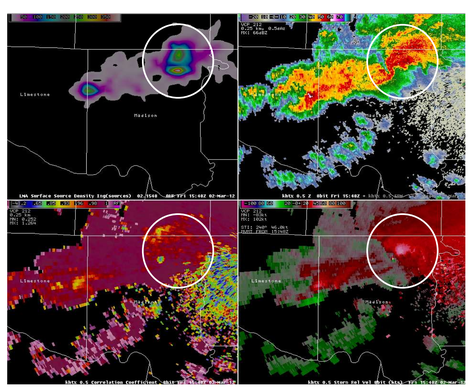


Figure 8 *(right)*: An AWIPS-1 display from 1548 UTC, as the tornado reached its peak intensity. Clockwise from top-left: NALMA source density, KHTX reflectivity, KHTX storm-relative velocity, and KHTX correlation coefficient (ρhv).

EF-2 Tornado: 1606 to 1615 UTC

- Second tornadic storm developed southwest of the first, and developed a tornado just 4.5 km (2.8 mi) south of the first tornado's path in Meridianville, AL
- Tornado occurred as a secondary maximum in source density was ongoing, and peaked in intensity as source density was peaking

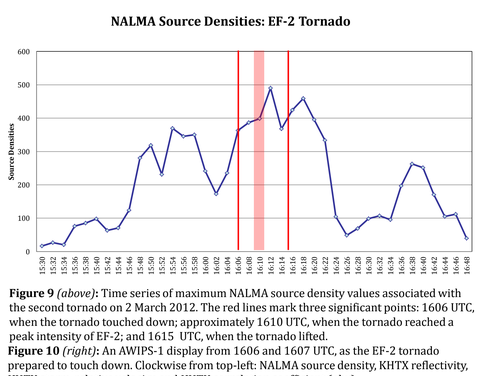


Figure 9 *(above)*: Time series of maximum NALMA source density values associated with the second tornado on 2 March 2012. The red lines mark three significant points: 1606 UTC, when the tornado touched down; approximately 1610 UTC, when the tornado reached a peak intensity of EF-2; and 1615 UTC, when the tornado lifted.

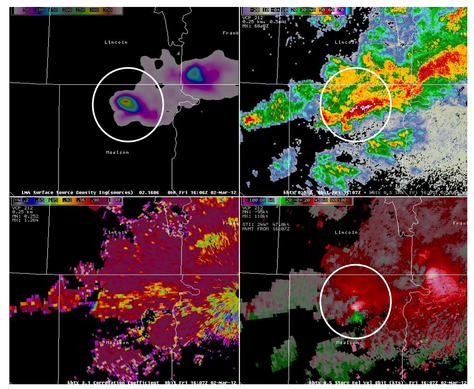


Figure 10 *(right)*: An AWIPS-1 display from 1606 and 1607 UTC, as the EF-2 tornado prepared to touch down. Clockwise from top-left: NALMA source density, KHTX reflectivity, KHTX storm-relative velocity, and KHTX correlation coefficient (ρhv).

IV. Afternoon Weak Tornadoes and Large Hail

- Four weak tornadoes (two EF-1s and two EF-0s) occurred after 1900 UTC, all of which occurred within a 24 km (15 mi) radius in Limestone County, AL, and Lincoln County, TN
- Two supercells produced three of the tornadoes and instances of baseball to softball size hail
- Marked increases in source density occurred as the storms entered the heart of the NALMA network near Huntsville, and values fell off as they exited. At the time, the network was operating with fewer-than-normal sensors due to damage from the 27 April 2011 tornado outbreak (since restored). In general, afternoon storms indicated smaller source density values than morning activity.

- Most pronounced jump (~4σ) with the first supercell occurred at 1944 UTC, 11 minutes before an EF-0 tornado touched down in northwestern Limestone County, AL
- Additional jumps preceded three severe hail reports ranging from quarter-size (14 min lead time) to baseball size (just 1 min lead time)
- Milder lightning increases (not always jumps) occurred prior to all severe reports

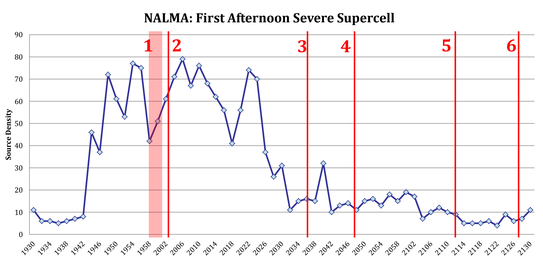


Figure 11: Time series of maximum NALMA source density values associated with the first afternoon supercell on 2 March 2012. The red lines mark significant reports associated with the supercell:
(1) EF-0 tornado in northwestern Limestone County, AL from 1955 to 1959 UTC;
(2) 2.54 cm (1 in; quarter-size) hail report at 2000 UTC in northeastern Limestone County, AL;
(3) 4.45 cm (1.75 in; golf ball-size) hail report at 2035 UTC in southern Lincoln County, TN;
(4) another 4.45 cm (1.75 in; golf ball-size) hail report at 2045 UTC in southern Lincoln County, TN;
(5) 2.54 cm (1 in; quarter-size) hail report at 2110 UTC in central Franklin County, TN;
(6) 7 cm (2.75 in; baseball-size) hail report at 2125 UTC in east-central Franklin County, TN.

- Most pronounced jump occurred 2 minutes before an EF-0 tornado touched down in northern Limestone County, AL; a smaller jump preceded the tornado by 20 minutes
- Like the first supercell, increases (not always jumps) occurred before nearly all severe weather reports; however, each increase did not correlate to a severe weather report (limiting the real-time operational utility)

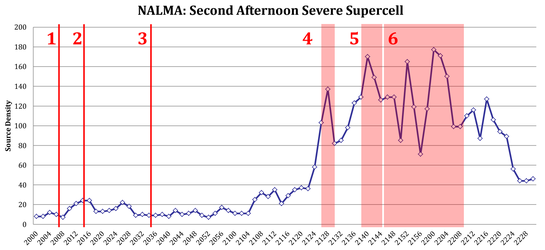


Figure 12: Time series of maximum NALMA source density values associated with the second afternoon supercell on 2 March 2012. The red lines mark significant reports associated with the supercell:
(1) 2.54 cm (1 in.; quarter-size) hail report at 2007 UTC in extreme western Colbert County, AL;
(2) 7 cm (2.75 in; baseball-size) hail report at 2015 UTC in western Colbert County, AL;
(3) 10.8 cm (4.25 in.; softball-size) hail report at 2035 UTC in central Lauderdale County, AL;
(4) EF-0 tornado in northern Limestone County, AL from 2126 to 2131 UTC;
(5) EF-1 tornado in northeastern Limestone County, AL from 2139 to 2146 UTC;
(6) numerous large hail reports (ranging from 2.54 cm to 4.45 cm) in extreme northern Madison County, AL, from 2145 to 2209 UTC.

Future Work

- Launch of Geostationary Lightning Mapper (GLM) aboard GOES-R will bring nearly full-disk total lightning information. It will have lower resolution but will not be subject to detection efficiency/ ground-based network outage issues (as in this case).
- Joint SPoRT/NWS development to provide better real-time lightning trend information in AWIPS 2
- Additional research into the relationship between total lightning and tornado intensity in long-track tornadoes (like the EF-3 in this case)
- Additional research regarding operational total lightning in other impact weather cases