Predicting High-Shear and Low-CAPE Tornadoes using Goes ABI Band 11 (8.5 µM) Satellite Data: A case study of the March 3, 2019 Beauregard, Alabama and March 3, 2020 Cookeville, Tennessee EF4 Tornadoes

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ABSTRACT

Tornadoes are among the deadliest atmospheric phenomenon observed on earth, capable of shattering and changing towns, structures, and lives forever. Recent trends have indicated that notable fatal tornado cases are both shifting to the southeastern United States, a region that is considerably more populated than the Great Plains, and are occurring in high-shear low-CAPE (HSLC) environments, which cause many forecasting and prediction issues. Since the atmospheric ingredients that need to come together for HSLC tornado setups are rarely obvious beforehand, forecasters are seldom confident in HSLC events until it is too late. As a result, public awareness for HSLC tornado events is very low and often non-existent until the tornado strikes, causing HSLC tornadoes to be deadlier than other tornado setups when they occur. These issues proved catastrophic during two tornadoes, the March 3rd, 2019 Beauregard, Alabama EF4 Tornado and March 3rd, 2020 Cookeville, Tennessee EF4 Tornado, which were the two deadliest tornadoes in the United States between June 2013 and December 2021. Therefore, it is critical that research is conducted to find a way to predict HSLC tornadoes further ahead of time. The Beauregard and Cookeville tornadic supercells were closely analyzed using GOES-16 ABI Band 11 (8.5 µm) data. The research revealed specific trends in both of the parent tornadic supercells on satellite prior and during the tornadoes, which may be identified and used by meteorologists to predict HSLC tornado events with more accuracy and lead time. This research will be beneficial for meteorologists in identifying and acting on HSLC tornado events as early as possible, which will undoubtedly save lives in the future.

Figure 5 (Above): This image shows EF4 tornado damage south of Beauregard, Alabama after the tornado passed. 23 people lost their lives in this area alone. (DAVID GOLDMAN/AP)

RESEARCH QUESTION

How can significant tornado events in low-CAPE and high-shear environments be predicted, detected, and acted upon with more accuracy and effectiveness using GOES ABI Band 11 (8.5 µm) satellite data?

METHODS AND DATA PART 1: MARCH 3, 2019 BEAUREGARD, AL TORNADO

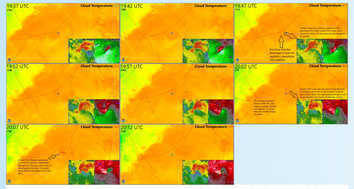
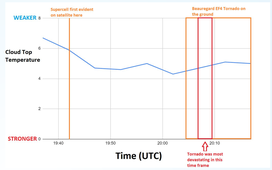


Figure 1 (Above): This image shows the GOES 16 ABI Band 11 (8.5 µm) Cloud Top Data of the evolution of the Beauregard Tornado from 19:37 UTC to 20:12 UTC. The Cloud Top Temperature is calculated in Spectral Radians. Radar data from the KMXX radar is overlaid and used to explain certain dramatic changes in the cloud temperature of the supercell. Click HERE for a larger version

- GOES-16 ABI Band 11 (8.5 µm) was analyzed in depth for the Beauregard Tornado (Click link to see enlarged Fig 1 for details)
- 19:37 UTC: A lot of severe storms can be seen in the Colombus, GA vicinity
- 19:47 UTC: A new updraft is evident on Band 11 (8.5 µm) data as a concentrated area of cooling cloud tops
- Cooling cloud tops indicate a strong updraft and possible supercell
- Band 11 (8.5 µm) data was used since it is really good at identifying storm and updraft strength
- 20:02 UTC: The new updraft intensifies more according to Band 11 (8.5 µm) data
- Cooling of cloud tops coincide with RFD surges (Click link to see enlarged Fig 1 for details)
- Echo tops remained prominent but consistently cool from 19:47 - 20:02 UTC
  - This could be used as a signal for public officials to take safety measures for those in path of this storm



- GOES-16 ABI Band 11 (8.5 µm) cloud temperatures were analyzed in depth for the Beauregard Tornado (Fig 2 above)
- A significant cooling in cloud temperature was noted at 20:02 UTC approx 5 min before tornadogenesis
  - Similar feature occurred five min before the Cookeville Tornado formed (see Fig 3
  - Could indicate that an HSLC tornado is about to form
- Echo tops remained prominent but consistently cool from 19:47 - 20:02 UTC
  - This could be used as a signal for public officials to take safety measures for those in path of this storm

METHODS AND DATA PART 2: MARCH 3, 2020 COOKEVILLE, TN TORNADO

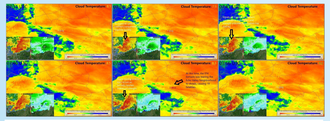
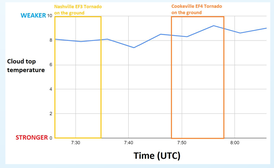


Figure 3 (Above): This image shows the GOES 16 ABI Band 11 (8.5 µm) Cloud Top Data of the evolution of the Cookeville Supercell from 07:27 UTC to 08:07 UTC. The Cloud Top Temperature is calculated in Spectral Radians. Radar data from the KOHX radar is overlaid and used to explain certain dramatic changes in the cloud temperature of the supercell. Click HERE for a larger version

- GOES-16 ABI Band 11 (8.5 µm) was analyzed in depth for the Cookeville Tornado (Click link to see enlarged Fig 3d for details)
- 07:31 UTC: A supercell begins to lose organization and splits in half as the long-tracked Nashville EF3 tornado is dissipating
- 07:36 UTC: A new echo top cooling is evident on Band 11 (8.5 µm) data as the northern of the two components begins to organize quickly
- 07:41 UTC: Band 11 (8.5 µm) data shows a major top cooling with the storm as the northern component continues to organize
- 07:51 UTC Band 11 (8.5 µm) data highlights a slight cooling of echo tops as the tornado (and upwards velocity) reaches maximum strength
- 07:56 UTC: The southern component looked organized on radar, but only resulted in only a brief tornado and had no echo top cooling visible on Band 11 (8.5 µm) data
- Major cooling of cloud tops was associated with significant organization of eventually tornadic northern component from 07:36 - 07:41 UTC
  - This could signal higher confidence in a new tornado in a supercell that already had multiple tornado reports with it



- GOES-16 ABI Band 11 (8.5 µm) cloud temperatures were analyzed in depth for the Cookeville Tornado (Fig 4 to the left)
- Significant cloud top cooling was noted between 07:36 and 07:41 UTC as eventually tornadic northern component quickly organized (see Fig 3 also)
  - Similar feature occurred five min before the Beauregard Tornado formed (see Fig 2)
  - Could indicate higher confidence that an HSLC tornado is about to form
- The component of the supercell that went tornadic had a major cloud top cooling while the component of the supercell that didn't go significantly tornadic did not
  - Despite non-significantly tornadic component looking "more organized" on radar reflectivity

DISCUSSION OF DATA

- The Cookeville Supercell had produced six tornadoes before the Cookeville Tornado
  - Explains why there wasn't a sharp initial decrease in cloud temperatures but rather a constant cloud temperature before this tornado occurred when comparing to the Beauregard Tornado (see Fig 3 and Fig 4)
- The Beauregard Supercell was in close proximity to the KMXX radar
  - The biggest cloud temperatures could be confirmed to be associated with RFD surges (see Fig 1)
    - RFD surges are known to have been associated with tornadogenesis and supercell intensification in the past
- The Cookeville Supercell was located much further away from the nearest radar than the Beauregard supercell was
  - The lone drop in cloud temperatures cannot be confirmed to have been from an RFD surge as a result
- The Beauregard environment had slightly more instability than the Cookeville environment did
  - Cause of warmer cloud temperatures in the Beauregard Supercell than the Cookeville Supercell (see Fig 3 and Fig 4)
- Goes-16 ABI Band 11 (8.5 µM)was particularly useful for multiple reasons
  - Has great ability to assess the strength of a supercellular updraft based on satellite cloud temperature data alone
  - Can observe supercell updraft strength at night, which is when several famous HSLC tornadoes have occurred in the past
  - Can detect sudden changes in the strength of any supercell's updraft based on changes in cloud temperature

References

GOES 16 Band 11 Cloud Top Satellite Data: https://noaa-goes16.s3.amazonaws.com/index.html

KMXX and KOHX NEXRAD Radar Imagery: NEXRAD Data Inventory Search | National Centers for Environmental Information (ncei.noaa.gov)

Image of Beauregard Tornado Damage: Aerial photographs reveal the utter devastation caused by the 170mph Alabama tornado one | Daily Mail Online

Image of Cookeville Tornado Damage: Reeling from deadly tornadoes, Middle Tennessee confirms its 1st case of coronavirus - ABC News (go.com)

WCT Toolkit: NOAA's Weather and Climate Toolkit (Viewer and Data Exporter)

GR2Analyst Radar Software: GR2Analyst Main Page (grlevelx.com)

NWS Damage Assessment Toolkit (for official survey information): ArcGIS Web Application (noaa.gov)

NCDC Storm Database: Storm Events Database | National Centers for Environmental Information (noaa.gov)

RESULTS and CONCLUSIONS

- Band 11 was particularly useful for multiple reasons
  - Has great ability to assess the strength of a supercellular updraft based on satellite cloud temperature data alone
  - Can observe supercell updraft strength at night, which is when several famous HSLC tornadoes have occurred in the past
  - Can detect sudden changes in the strength of any supercell's updraft based on changes in cloud temperature
- Supercells that are sustaining themselves in HSLC environments will maintain a sufficiently cold temperature signature on satellite for some time prior to tornadogenesis (see figures 4 and 5 below)
  - This indicates the presence of a healthy and persevering supercellular updraft, which could alert meteorologists to pay attention to this storm in particular
- A sudden decrease in cloud temperature that can be detected by satellite occurs just prior to major tornadogenesis in HSLC environments (see figure 1 at left and 4 and 5 below)
  - This, combined with radar evidence can be used to increase confidence that an RFD surge is occurring
  - Either the supercell is becoming even stronger, a tornado is about to occur, or both
- These trends on satellite can be used by meteorologists to identify supercells in HSLC environments that may become tornadic well in advance
  - Public Officials could alert citizens with another hour of lead time
  - Protective action can be taken much further in advance than seeing the tornado itself
  - You're ALWAYS SAFER WHEN YOU TAKE ACTION AHEAD OF TIME THEN
- Certain satellite features that may be visible during dryline and CAPE-driven tornado setups are rarely obvious with HSLC setups
  - Cloud deck precludes surface heating and instability
  - Especially an issue at nighttime when Band 1 - Visible Data is useless
- The most effective and accurate way to predict HSLC tornadoes in advance is by tracking storm behavior on satellite and radar
- Vertical tilting of streamwise vorticity is essential for tornadoes and vertical updrafts
  - A cloud top cooling will indicate that vertical processes in a supercell are strong and that may indicate higher tornado or severe weather potential
  - Can be used to warn for all types of dangerous severe weather!
- This research may be used as a catalyst for other research into HSLC tornado-producing thunderstorms in the future