Rare polarimetric tornado debris signatures (TDS) in the Appalachian region and the use of remote sensing techniques to assist with the 24 February 2016 EF3 survey in Virginia

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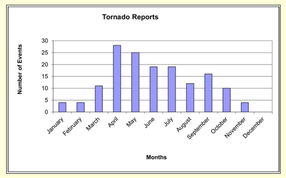
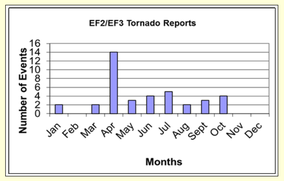
24 February 2016 TDS with EF3 in Virginia

- A rare February EF3 with path length of 27 km (17 mi), resulting in one fatality and seven injuries, occurred near a surface warm frontal boundary in central Virginia. The first EF3 in NWS Blacksburg VA County Warning Area (RNK CWA) since March 1998. First recorded **February** EF3 or stronger *ever* in RNK CWA (records since 1950).
- Part of a larger outbreak of tornadoes from South Carolina to Pennsylvania.
- The EF3 occurred at relatively long ranges from area Doppler radars (WSR-88D).
- Two radars (KFCX and KAKQ) detected a TDS despite the long range, and this was the first known TDS signature observed from the KFCX radar. Debris was likely a combination of materials from houses as well as trees.

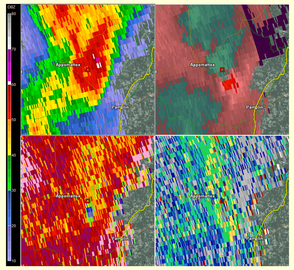




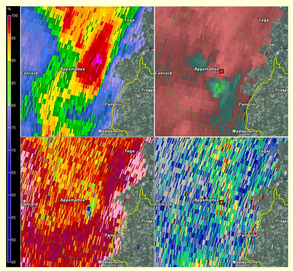
Monthly climatology within the RNK CWA for all tornadoes (left) and EF2 and stronger tornadoes (right), from 1950-2013. No known EF4 or stronger has occurred in the CWA.

Appomattox County, VA EF3, on the ground from 2027 – 2044 UTC

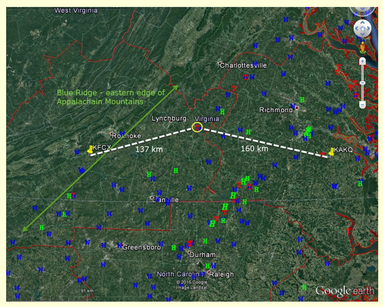
WSR-88D 0.5° 4-panel products from KFCX radar (left), and from KAKQ radar (right). Product times labeled under each 4-panel image. Products are as follows: Reflectivity in upper left; storm-relative velocity in upper-right; correlation coefficient (CC) in lower-left; differential reflectivity in lower-right. Radar products courtesy of Gibson Ridge (GR2Analyst software).



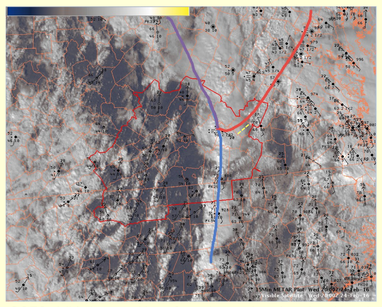
TDS seen from KFCX at a range of 137 km toward the east-northeast, 0.5° elevation angle, thus viewing ~2900 m AGL (KFCX is 990 m AGL). Time: 2035 UTC. Color scale on left is for reflectivity (upper right).



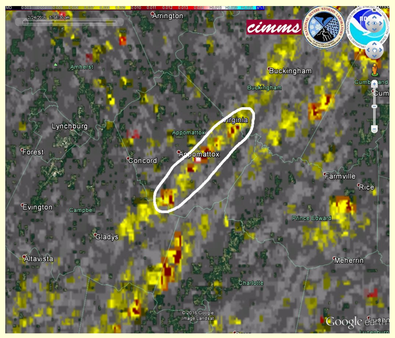
TDS seen from KAKQ at a range of 160 km toward the west-northwest, 0.6° elevation angle, thus viewing ~2800 m AGL. Time: 2037 UTC. Color scale on left is for CC (lower-left).



Preliminary storm reports across the region for 24 February 2016. Tornadoes are in red, severe wind reports in blue, severe hail reports in green. The Appomattox County EF3 is circled (middle of track), and locations of KFCX and KAKQ WSR-88Ds are tagged in yellow pins, and ranges to the tornado are marked with dashed line.



GOES visible image with surface observation plotted and hand-drawn positions of frontal boundaries; valid at 2000 UTC. Track of the Appomattox County EF3 (2027 – 2044 UTC) is marked with yellow dashed line.



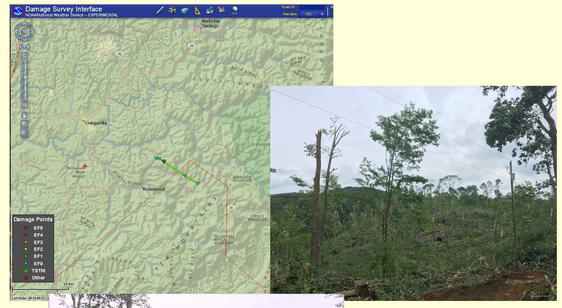
Multi-Radar Multi-Sensor (MRMS) 0-2km rotational shear product (16-22 UTC). Circled area highlights the Appomattox EF3. Other rotational tracks seen here produced no known tornadoes. Image provided by National Severe Storms Laboratory (NSSL) in KML format, but MRMS data was also available in AWIPS at the NWS in real-time.

Appomattox County tornado near Evergreen. Photo by Jason Smith.

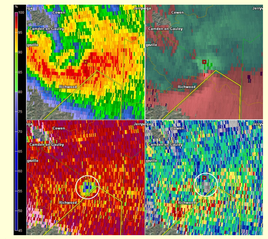
Damage photos from NWS survey of the Appomattox County EF3.

21 June 2016 TDS with EF1 in West Virginia

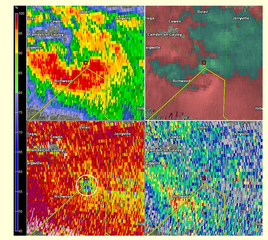
- EF1 had path length of 8.5 km (5.4 mi), entirely in National Forest
- TDS detected by WSR-88D KRLX up to a height of ~2500 m AGL
- ZDR values were largely negative within TDS, suggesting trees/branches lofted mostly in vertical position



Damage track of EF1 (top left) showing path mainly through complex terrain within Monongahela National Forest, and damage photos showing multiple trees snapped. Tornado on the ground from 1900 – 1909 UTC.



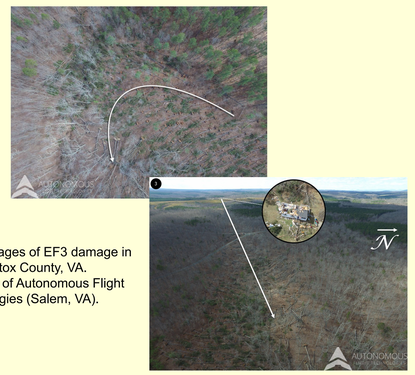
Same description as 4-panel radar images to the left, but TDS seen from KRLX on 21 June 2016 at 1901 UTC, ~95 km to the east. 0.5° beam height was viewing ~930 m AGL. White circles highlight signatures in CC and ZDR products respectively. Color scale on right is for CC (lower left).



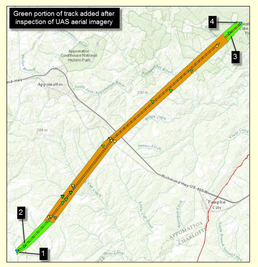
Same as above but for the 1.3° beam and at 1906 UTC. Beam height viewing ~2600 m AGL.

Remote sensing assistance for 24 Feb EF3 damage survey

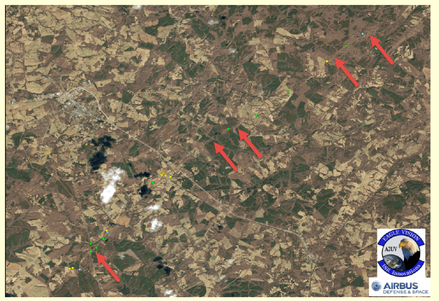
- Areal images from unmanned areal system (drone) from Autonomous Flight Technologies used to extend length of initial ground-based survey by ~6 km
- High resolution satellite imagery helps confirm damage track location



Aerial images of EF3 damage in Appomattox County, VA. Courtesy of Autonomous Flight Technologies (Salem, VA).



Aerial imagery assisted in extending track at beginning and end by a total of ~9km beyond what ground survey determined (additions shown in green)



Satellite image from "SPOT 6" (DOD) obtained from request via USGS Hazards Data Distribution System (image owned by Eagle Vision). Taken on 3 March 2016. ~6 m resolution. Shows evidence in some locations (red arrows) of the damage track.

Summary

- Dual-polarimetric data helped confirm tornado debris in two cases this year, and in one instance (Feb 24) at a relatively long range, suggestive of a potentially strong tornado. These were the first TDS detections by the KFCX radar since dual-pol installation in late 2012, and the first by neighboring radars for tornadoes in the RNK CWA. RNK forecasters have now become attuned to monitoring dual-pol data and more prepared to use "radar-confirmed" wording in warnings and update statements.
- Emerging technologies such as drones and access to high resolution satellite imagery can help to confirm and/or enhance tornado damage paths, and potentially find ones that otherwise might be difficult from ground searches. Research needs to continue on satellite detection of tornado tracks, especially in forested areas, to determine what resolutions and spectral bands are most useful for detecting damage paths of varying tornado intensities.