# Review of Geosciences-526376

**Title:** The College Park, Maryland Tornado of 24 September 2001

**Authors:** Pryor, Wawrzyniak, and Zhang

This study is now designated as a forensic study: see lines 76-79.

# Reviewer #1:

# Responses to Major Comments:

1. A continued concern with this study is I still do not understand what the authors are trying to convey to the scientific community.
   * This study is now claimed to be a historical study. But ultimately, not much has changed: as it was before, this manuscript represents a meteorological case study, including

synoptic-scale overview and remote sensing observations.

This study is now designated as a forensic study: see lines 76-79.

* + It is then claimed that the paper now has a focus on tornadoes in coastal climates based on the Kent Island tornado. The motivation also included some talk about tornadoes in east Asia. Yet, after the first section, *discussion of this case within the context of coastal*

*climates is never mentioned again*. And no mention is made about what exactly the authors are trying to learn about tornadoes in the coastal area (e.g., are they different from other tornadoes, are they becoming more common, do they form in different

environments, different structure, etc.). But no explicit comparisons are made with any cases except a non-coastal case from OK (see below). If this paper is supposed to be about coastal tornadoes, a complete overhaul is needed to address what it is the authors

want to learn about coastal tornadoes via a case study of the College Park tornado.

Removed all references to coastal climates.

* + Then, there is a lot of discussion about comparing this event to the Moore-Bridge Creek,

OK tornado because they are both long-track tornadoes that impacted populated areas. However, the focus of the paper is not on how this tornado impacted populated areas (as in, for example, Wurman et al. 2007), and the rest of the paper discusses their supposed

similar environments. If the focus of the paper is not on something to do with populated

areas, I don’t understand why the Moore case is used as a point of comparison. There is nothing dynamically different about tornadoes that hit populated areas and those that do not, it is a game of chance. In that case, why wouldn’t the authors look at other long-track supercells in the coastal region of Maryland/DC (Fig. 2 shows there are plenty to choose from) rather than a much stronger tornado that occurred in a very different geographical area?

Removed all references to the Moore OK tornado. This paper now focuses primarily on the College Park tornado with a brief discussion of two additional significant long-track tornadoes that occurred in the greater Washington, DC area during the following 3-year period.

* + There is talk that the College Park tornado shared many similarities with tornadoes in

China and Japan, perhaps related to the importance of RFD surges. I’m not sure if this is supposed to be a motivation too or if it’s part of the coastal tornado motivation, or if it’s just an extraneous sentence. Regardless, that possibility also is never mentioned again.

Removed all references to tornadoes in China and Japan. This paper now focuses primarily on the College Park tornado with a brief discussion of two additional significant long-track tornadoes that occurred in the greater Washington, DC area during the following 3-year period.

This study is now designated as a forensic study: see lines 76-79. This now serves as the motivation for the paper.

1. My second concern is the low quality of the analysis section, including some basic mistakes that are made and other questionable comparisons with past work.
   * As I discussed last time, the authors cite the similarity of this supercell with a supercell in Japan without acknowledging that all of the similarities are actually ubiquitous features in supercells.

Removed all references to tornadoes in China and Japan. This paper now focuses primarily on the College Park tornado with a brief discussion of two additional significant long-track tornadoes that occurred in the greater Washington, DC area during the following 3-year period.

* + The authors ignore one of the most important environmental conditions supportive of

tornadogenesis: LCLs. The sounding in Fig. 5 calculates the LCL at just 400 m AGL, a

very low cloud base. Many past studies have shown tornadoes are supported when LCLs

are low (e.g., Rasmussen and Blanchard 1998).

Noted. We have included analysis of the LCL parameter and its importance in fostering tornadogenesis. See lines 213-223: “In addition to the presence of an EML and PI layer, the lower-to-middle tropospheric lapse rate and lifted condensation level (LCL) were considered as major factors for tornadogenesis. Craven and Brooks (2004) noted in their study of sounding-derived parameters associated with deep moist convection that significant tornado environments featured 0-3 km above ground level (AGL) temperature lapse rates greater than 6 °C km-1 and mean layer LCL (MLLCL) heights below 1000 m. For the College Park tornado, 0-3 km AGL lapse rate was calculated to be 7 °C km-1 while most unstable parcel LCL (MULCL) and MLLCL were calculated to be 353 m and 791 m, respectively. Large temperature lapse rates are often an indicator of an EML and promote strong conditional instability. Very low LCLs enhance tornado potential by limiting subcloud evaporation and decreasing the potential for cold outflow that could interfere with the developing mesocyclone (Craven and Brooks 2004).”

* + The use of the MWPI in this study is not justified. This is a case study of a tornadic supercell, not a microburst. There seems to be some confusion both about how supercell RFDs form and what their contributions are to tornadogenesis. RFDs do not form like the convective downdrafts that traditionally lead to microbursts. Based on recent studies of

what causes RFD surges in supercells, a large vertical dynamical perturbation pressure

gradient force contribution originates from vertical gradients in rotation (e.g., Skinner et

al. 2015; Schenkman et al. 2016). This mechanism is distinctly different from traditional microburst generation driven by negative buoyancy, evaporation, and water loading. RFD

outflow winds can be quite strong and can certainly cause damage, but they should not be

treated as microbursts. This discussion should be removed.

Removed the discussion of the MWPI. However, based on signatures apparent in the sounding profile and GOES IR BTD imagery shown in Figure 7, we still believe a general discussion of the role of mid-tropospheric unsaturated air entrainment in RFD generation is still necessary for this case. Wakimoto (2001) identifies the forcing factors for RFD development that are similar to downburst forcing: condensate loading and evaporational cooling (see section 7.4a, Table 7.3). See:

Wakimoto, R.M., 2001: Convectively driven high wind events. In Severe convective storms (pp. 255-298). American Meteorological Society, Boston, MA.

* + Similarly, repeated claims (lines 330-31, 348-50, 391-92, 443-44), are made of the

importance of supposed dry air intrusion into a precip. core as fueling the RFD outflow

air “energy” that caused a tornado to form. There is no evidence to back up this claim. I

don’t know how the authors can look at Figure 7 and discern any detail about processes

that occur on the scales affecting tornadogenesis. It is true that RFD outflow air is thought to be important for tornadogenesis, both in the kinematic contribution of surges to genesis (e.g., Kosiba et al. 2013) and the RFD air’s thermodynamic character (i.e., more buoyant RFD outflow air is supportive; Markowski et al. 2002). It is also well known that an influx of very strong outflow is often bad for tornado production or maintenance based both on the introduction of a lot of negative buoyancy at the surface and the tendency for strong outflow to lead to vertically tilted updraft structure that reduces the dynamic lifting needed for vorticity tilting and stretching (e.g., Marquis et al. 2012). There are many other possibilities contributing to tornado production, for example baroclinic generation along the forward (left) flank convergence zone (e.g., Beck and Weiss 2013) or even frictional generation of vorticity (Schenkman et al. 2014). Therefore, using 4-km satellite data to identify likely contributors to tornado formation without any other supporting evidence is not warranted given that these processes that occur rapidly over very short spatial scales (< 1 km).

See previous comment. Wakimoto (2001) identifies the forcing factors for RFD development that are similar to downburst forcing: condensate loading and evaporational cooling (see section 7.4a, Table 7.3). In section 3, we highlight the factors that are apparent in the sounding profile and GOES IR imagery: “Facilitated by strong southwesterly winds of 20 to 25 m s-1 (40 to 49 kt) in the EML as displayed by the hodograph in the sounding profile , the interaction of unsaturated environmental air with the heavy precipitation core likely provided downdraft energy for intense storm outflow winds that initiated and sustained the tornado.”

* + The radar images in Figs. 9-10 show a textbook example of tornadic vortex signature (TVS). The TCS terminology cited was used in that particular 3 May 1999 study for a very large tornado and has not been adopted by the community. The College Park

signature is a TVS. Recommend removing all discussion about a TCS.

Noted. Upon consulting Brown et al. (1978), the radial velocity couplet identified in Figures 8-9 do constitute a TVS. Thus, all references to the “TCS” have been changed to “TVS”. See lines 333-337: “Brown et al. (1978) identified and defined a tornado vortex signature (TVS) as a couplet of “mean Doppler velocity extrema that occur about one beamwidth apart, regardless of vortex size or strength”. In a similar manner, the associated TVS in the present case was readily apparent in radial velocity imagery between 2121 and 2146 UTC, in Figs. 8f and 9, as a couplet of azimuthally adjacent maximum outbound (red shading) and inbound (blue shading) velocities located near College Park.”

* + The authors claim that an asymmetric convergence signature is evidence of a downburst occurrence (lines 389-92). The radar signature of a downburst is the opposite of what is shown: a divergence signature. The storm was moving toward the northeast (i.e., a component of motion away from the radar). Therefore, the asymmetric ground-relative flow arises from the translational motion of the storm being added to the in-storm convergence signature (in other words, the storm-relative flow would be closer to

symmetric).

Noted. Removed this discussion of a convergence signature and included a statement pertaining to role of translational motion in the velocity asymmetry of the TVS. See lines 341-343: “The asymmetry of the TVS was likely due to the increasing translational motion of the parent supercell toward the northeast at 15 m s-1 (30 kt).”

* + The authors claim there is a RFD surge based on radar images Fig. 9d,f. I do not see any evidence that this is accurate. The outbound velocities do not appear to change much,

though it is hard to tell because the figures are zoomed out so much. The RFD gust front

can be very difficult to identify in single-Doppler radar data, especially using data with

poor spatial resolution (~50 km away with a 1.0 degree beamwidth). Can the authors explicitly point out where the RFD surge is in these images and provide raw radial velocity numbers to quantify it for the reader?

Noted. Removed all references to the RFD surge.

# Minor Comments:

Line 11: “long-track” instead of “long-tracked”

Changed

Line 11: As I mentioned in the last review, meteorologically, “violent” tornadoes are those rated F4/5 or EF4/5 and tornadoes are described as “strong” for F2/3 or EF2/3.

Changed “violent” to “strong”.

Line 56: Why is the tornado track discontinuous? This figure shows two separate tornado tracks.

Explained in section 3: “A secondary RFD surge most likely occurred between 2136 and 2146 UTC when outbound velocities again increased to become significantly greater than inbound velocities. During this time period, non-tornadic (i.e. downburst) wind damage was observed in the Laurel area, where there was a break and subsequent westward shift in the tornado track.”

Line 59: Indicate what the track is based off of. Official survey from the NWS?

Yes: National Weather Service, 2001: Storm Data and Unusual Weather Phenomena, September 2001. Available online at https://www.weather.gov/lwx/stormdata

Line 74: Its nighttime occurrence made it potentially more “dangerous” than formidable.

Changed “formidable” to “dangerous”.

Lines 123, 246, 276, 334, 507, etc.: “tornadogenesis” is one word.

Corrected

Line 192: typo “the equivalent…”

Corrected

Lines 298-306: I’ve tried hard to identify details of the particular storm in Fig. 6 and really cannot. Please zoom in the figure so that the reader can get better detail of the supercell.

Figures 6 and 7 have been revised: zoomed and re-calibrated to highlight the structural features of the supercell storm.

Lines 303-06: Suggest adding a reference here.

Not necessary.

Line 308: Please use a different color and size for the arrows in Fig. 6, they are very difficult to see.

Figures 6 and 7 have been revised: zoomed and re-calibrated to highlight the structural features of the supercell storm.

Line 337: I do not see a blue curve anywhere on any of these panel images marking a cold front.

Reference to cold front has been removed.

Lines 387-403: Please cite figure panels (e.g., Fig. 8c) within the discussion so the reader can easily identify which panel is being identified.

Figure panel citations added.

Line 388: Should this time be 2120 UTC?

Yes- corrected.

Line 390: Should this time be 2116 UTC?

Yes-corrected.

**Reviewer #2- Responses to minor comments**

L54- There should probably be a citation for damage values, etc. (I’m guessing this is from Storm Data?).

Yes- added the citation “National Weather Service 2001, available online at <https://www.weather.gov/lwx/stormdata>”. Also added the corresponding reference:

National Weather Service, 2001: Storm Data and Unusual Weather Phenomena, September 2001. Available online at <https://www.weather.gov/lwx/stormdata>

L126: If referring to a DRC, this should be cited, see:

Was there any evidence of DRC for this case?

Yes- evident as an increase in reflectivity in the hook echo between 2111 and 2126 UTC as displayed in Figures 8-9. Added the citations and references to Rasmussen et al. and Kennedy et al., respectively.

L154: might be extra space prior to Doppler?

Corrected – removed extra space.

L169-173: I would wordsmith some of this, since the description is nearly verbatim with the description on the NCAR RDA.

Modified the text in this section to now read: “The NCEP FNL Operational Global Analysis, with 1-degree by 1-degree resolution and six hourly update cycle, is generated from the Global Data Assimilation System (GDAS). The FNL analyses are generated by the same model used in the Global Forecast System (GFS) about an hour after the GFS is initialized, resulting in the ingestion of more observational data. The GFS uses the FNL from the previous 6-h cycle as part of its initialization.”

Figure 3: Can you change the black dot to a color so it is more prominent?

Yes – Black dot in Figure 3a has been replaced with a larger blue dot and replaced in Figure 3b with a larger red dot.

L246/276 (and onward): tornadogenesis (one word)

Corrected

L300: (and as evidenced by the hodograph shown in Fig. 5)

Included this statement into line 301.