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Interactive comment on "A dynamic and thermodynamic analysis of the 11 December 2017 tornadic supercell in the Highveld of South Africa" *by* Lesetja E. Lekoloane et al.

Anonymous Referee #1

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The authors of this manuscript present a case study of a tornadic supercell that affected parts of South Africa and led to extensive damage and injuries due to severe weather including a tornado that hit Vaal Marina in Gauteng Province. The study is relevant given the low number of tornado / supercell case studies in South Africa and can help to better understand conditions favorable for severe weather is this part of the country. I therefore recommend publication in Weather and Climate Dynamics. However, work is needed to increase the value of this paper since I have some concerns regarding some of the results presented in the conclusions, in particular the presented model forecasts.

Major comments

1) Results that need to be discussed in much greater depth to convince the reader

"SA1.5 underestimated mid-level vorticity due to a significant underestimation in low-level warm moisture advection and convergence." The lack of mid-level vorticity and low-level moisture flux convergence in the model field could be a consequence of the missed convection initiation. In other words: High mid-level vorticity and strong low-level moisture flux convergence would be a consequence of a supercell that develops in the model forecast. Since the model failed to initiate storms, it is also not able to increase the low-level moisture flux convergence and mid-level vorticity. See also lines 340-343: "The poor performance of SA1.5 seems to have emanated from a significant underestimation in low-level warm moisture advection and convergence (which act as dynamic lifting mechanisms), and as a result the mid-level vorticity being greatly underestimated, which led to the storm not being initialised."

"SA4.4 captured the supercell but underestimated its severity due to an underestimation in mid-level vorticity found to be one order of magnitude smaller than that of a typical mesocyclone." Since SA4.4 has limited resolution, wouldn't you expect that this already causes the vorticity of modelled supercells to be smaller?

"This was a result of underestimation in surface to mid-level wind shear and low-level horizontal mass and moisture flux convergence." Again, please discuss if the model resolution allows to directly indicate the effect of the developed convective storm on the presented parameters. Is it possible that you just analyse difference fields in the model that are affected by the initiated convective storm and therefore cannot be used to explain why a storm has formed or not? See also lines 283-287: "A relationship between MFC and vertical vorticity was also determined. It was found that SA4.4 predicted vorticity maxima at 500 hPa that is associated with MFC maxima at 800 hPa. MFC initiates first at 800 hPa followed by vorticity genesis at 500 hPa (Fig. 9(c)). This implies that the development of MFC in the low-levels could be a precursor of vertical vorticity initiation in the mid-levels. Since there is a positive relationship between low-level MFC and mid-level vorticity, it follows that the stronger the low-level MFC, the stronger the mid-level vorticity would be." It needs to be clear which of the presented model data are a consequence of convection initiation rather than ingredients for convective storms.

2) Ingredients-based methodology

I miss an analysis of the main ingredients for convective storms. These are low-level moisture, (mid-level) lapse rates, and lift. For low-level moisture and lift, I would highly appreciate a surface analysis including temperature, dewpoint, and wind barbs. The 15 UTC chart clearly indicates the presence of a dryline and shows the advection of moist air masses ahead of it. Are these drylines typical for that region or was this event special with respect to the intensity or location of the dryline? Two ascents have been operated at 9 UTC in the area of interest to indicate the presence of lapse rates (I recommend including FABL Bloemfontein Airport since it shows deep boundary layer mixing upstream although it is farther away). Please discuss if these soundings are representative since the launch time is many hours prior to the discussed event. Please check the sounding time. In the manuscript, the presented sounding is said to be launched at 12 UTC, but according to raw data it is launched at 9 UTC.

To discuss the magnitude of vertical wind shear, I also would include FABL Bloemfontein Airport sounding that has much greater mid-level winds upstream several hours prior to the event (45 knots at 500 hPa compared to 24 kts in the presented sounding).

Finally, dry mid-level air is not an ingredient for convective storms, e.g. lines 229-233: "The lower levels were moist with an average relative humidity of 91% between the surface and 625 hPa, while the mid-levels were dry with relative humidity averaging 26% between 573 hPa and 400 hPa. Therefore, the availability of low-level moisture, dry mid-levels, and vertical wind shearing provided favourable conditions for the possibility of dynamically and thermodynamically induced organised severe thunderstorms

(including supercell type) developing in the vicinity."

Further comments

1) Line 45: Single cells can produce severe weather, e.g., pulse storms.

2) Line 47: There can be also tornadoes not associated with intense convective storms (non-mesocyclonic tornadoes)

3) Line 79: Which criteria did you use to choose weather stations of interest? Please include a complete surface analysis that contains all data.

4) Figure 1: How did you produce the track of the cell? Radar site of the southern radar and the provincial borders are hardly visible in printed versions of the manuscript. Please include a reference scale.

5) Line 104-105: Please explain how the surface data were "regridded". What was the maximum distance between model grid points and surface data? Did you take terrain height differences into account? Was there an objective method to select proximity stations? Again, I would suggest a surface analysis.

6) Line 109: What was the distance of the radar sites from the supercell? You could solve this issue by including a reference scale in Figure 1.

7) Line 110-111: Please check the time between sounding launch and supercell event. The raw data file indicates that the soundings were launched three hours earlier. Please discuss if this has consequences for the classification as proximity sounding.

8) Lines 140-144: "The presence of boundary layer water vapour concentration is one of the most important factors for tornadogenesis (Markowski and Richardson, 2009). As a result, to analyse the significance of low-level moisture in the event considered, the convergence of moisture flux is computed at 800 hPa level. Moisture flux convergence (MFC) is a useful diagnostic tool as it combines the effects of moisture advection and convergence and can be computed at any atmospheric pressure level (Banacos

and Schultz, 2005)." MFC is not an ingredient for convective storms or tornadoes! Large MFC does not necessarily mean that moisture is high. Furthermore, at the observation sites shown in the paper, there is no moisture increase prior to the event. More discussion is needed to explain why you like to analyse MFC rather than moisture directly.

9) "This mid-level circulation patterns resulted in midatmospheric south-westerly winds over the interior of South Africa, which enhanced convective instability over the centraleast of the country as the dry mid-level air advects over the low-level warm and moist-air in the east." Dry mid-level air is not an ingredient for convective storms! There can be very dry air on top of very moist layers and still there is no instability. Please analyse the mid-level lapse rate field and look for regions where steep lapse rates overlap with rich low-level moisture to consider instability.

10) Figure 2: I would recommend using 300 hPa rather than 200 hPa.

11) Line 182-183: "A weak upper-air trough was also present over South Africa (Fig. 2(a))." If there is no further discussion on the upper level wind field, you may skip the 200 hPa chart. Otherwise, you may discuss in which way the upper trough / jet supported the development of a severe convective event.

12) Mesoanalysis: The presented data (Figures 3 and 4) are quite uncommon to analyse the mesoscale surface weather chart. A surface analysis would a good addition to these data.

13) Line 207: "After initiation, the storm initially propagated eastwards, then suddenly changed direction to north-east towards the Vaal Dam as it matured into a supercell thunderstorm through energy supply from a continual merger of several cells." This is very vague. Cell merger can also cause supercell decay due to the interaction of outflows. Why did this not happen in this case?

14) Mesoanalysis: I would re-organize this section. You start with surface observations,

jump to radar analysis, continue with the discussion of one surface observation that might be not representative, jump to the discussion of a sounding, jump back to radar analysis.

15) Line 260: It would be good to compare a surface chart directly to the winds in the lowest model level. The average regridded surface data does not allow for a detailed analysis. Furthermore, it is not explained how the averaging of the station data (due to which criteria are they chosen) is done.

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