1. Introduction

In a recent paper, Wissmeier and Goler (2009, hereafter WG09) presented the results of a numerical experiment meant to examine the different potential for convective storm splitting in the tropics versus the midlatitudes. WG09 found that simulated storms in tropical environments were less likely to undergo classical supercellular splitting because the storms’ outflow quickly spread out and cut the storms off from their source of inflow before the splitting process could occur. The main conclusion reached by WG09 is that higher vertical wind shear values are necessary for storm splitting to occur in the tropics than in the midlatitudes because the comparatively large vertical wind shear weakens and delays the convective outflow produced by storms. These are thought-provoking results and conclusions, but they hinge on some questionable assumptions and choices in the experimental design. The purpose of the present comment is to document and discuss several aspects of the study that bias WG09’s results and diminish the generality of their conclusions.

2. Comments on the relationship of storm splitting to severe weather

WG09 were largely motivated by the apparent inadequacy (according to forecasters in Darwin, Australia) of midlatitude severe weather indices as applied to tropical thunderstorms. This is a worthy problem, but it is curious that WG09 have chosen “storm splitting” to be their proxy for storm severity. For example, Keenan and Carbone (1992) document a number of squall lines in the Darwin area, some of which were presumably severe, and yet WG09 do not appear to consider this possible mode. Undoubtedly, supercells are the most intense among severe storms (e.g., Doswell 2001), and many supercells do indeed undergo the storm-splitting process (e.g., Weisman and Klemp 1982, hereafter WK82). However, it does not logically follow that every incidence of storm splitting is associated with severe weather (or vice versa).

As has long been known, environments in which the wind shear vector turns with height (i.e., a “curved” hodograph) have a tendency to suppress one of the two split members during or shortly after the storm splitting process (e.g., Weisman and Klemp 1984; Grasso 2000). In such cases, an intense long-lived supercell may result (in North America, usually the right mover) without a clearly defined storm split. In contrast, “straight line” hodographs (in which the shear vector does not change direction with height) produce classical mirror-image storm splits, which are commonly weaker (e.g., Davies-Jones et al. 2001). In other words, the existence of a storm split is not exclusively correlated with storm severity. WG09 elected to use straight-line wind profiles for their numerical experiments because they wished to extend the results of the previous study by WK82, but this raises the question of whether such wind profiles are actually representative of tropical thunderstorms. Many midlatitude supercell environments possess significant turning of the shear vector with height (e.g., Markowski et al. 2003). If it turns out that straight-line wind profiles are more common in the tropics/Darwin than in the midlatitudes, then that would be an appropriate avenue for trying to understand the apparent ineffectiveness of midlatitude forecasting indices1 in the Darwin area.

1 WG09 primarily considered the bulk Richardson number, which incorporates the wind profile only via a layer’s total bulk shear and has shown to be a somewhat poor operational discriminator between ordinary cells and supercells (e.g., Rasmussen and Blanchard 1998).
More generally, if a thunderstorm were to produce sufficiently copious outflow as to overwhelm the storm-splitting process (as suggested by WG09), it also seems likely that it would produce at least a few surface wind gusts that would satisfy the minimal criterion for severe winds. In short, the ramifications of WG09’s results for tropical severe weather forecasting are unclear. The remainder of this note focuses instead on what emerges as the main theme of WG09: the impact of rapid, strong outflow production on the potential for storm splitting.

3. Comments on WG09’s initial soundings

At the heart of WG09’s results is the finding that simulated storms in tropical environments (with moderate shear) have quickly spreading outflow that cuts the storms off from their source of inflow before splitting can occur. All of this hinges on the production of outflow by the initial storms, which are artificially triggered in their model. This section (and the next) documents ways in which WG09’s experiments unrealistically exaggerate the differences between outflow production in their tropical versus their midlatitude simulations.

It is fairly well established that, all other things being equal, strong outflows are favored in environments that have (i) higher CAPE (e.g., Srivastava 1985; Weisman 1993) and (ii) comparatively drier air in the low and mid-levels (e.g., Gilmore and Wicker 1998). Higher CAPE normally leads to stronger convective updrafts, which produce more total condensate and therefore have both increased hydrometeor loading and also an increased concentration of hydrometeors available for latent cooling (these points are upheld in the simple demonstration simulations in section 4). In addition, environments with large CAPE frequently have steeper lapse rates, meaning that there is less static stability resisting the downward displacements of the negatively buoyant air that is produced through latent cooling. Finally, drier environments can favor stronger outflows because a greater amount of latent cooling is possible before saturation is reached. The soundings used by WG09 unrealistically favor the comparatively greater production of strong outflow in their tropical simulations for these reasons.

First off, the values of CAPE utilized by WG09 are represented as being typical for tropical soundings but are in fact quite high. Many of the results of WG09 follow from an experimental design in which the tropical convective environments have much more CAPE than the midlatitude convective environments. Based on the climatologies of Rasmussen and Blanchard (1998) and Thompson et al. (2003), it is clear that supercell environments in the United States commonly have CAPE around 2000 J kg$^{-1}$. In this respect, WG09 have tested a reasonable part of the midlatitude CAPE distribution. However, the tropical soundings used in WG09’s tropical simulations range in CAPE from 3789 to 6084 J kg$^{-1}$, with a median value of 5305 J kg$^{-1}$ (i.e., a factor of 2–3 higher than for the typical midlatitude severe storm). Is this reasonable?

The climatology of Riemann-Campe et al. (2009) shows the Darwin area as being typified by CAPE in the 1000–2000 J kg$^{-1}$ range during its most unstable season (austral summer). But, since this is a long-term average, it is worthwhile to try to obtain some sense of the distribution (i.e., perhaps the most severe days in Darwin have much higher CAPE). Taken altogether, seven prominent studies from the Darwin area (top section of Table 1) reveal typical values for CAPE falling mostly between 1000 and 2500 J kg$^{-1}$, with slightly lower values in the Rutledge et al. (1992) study and the highest values in the Williams and Renno (1993) “offshore” subset. Admittedly, the tornadic cases of Keenan and Carbone (1992, their Fig. 15b) were typified by the highest CAPE (ranging from 2700 to 3700 J kg$^{-1}$). But even this maximal value of $\sim 3700$ J kg$^{-1}$ is slightly smaller than the minimal tropical value of 3789 J kg$^{-1}$ used in WG09’s experiments. Furthermore, a large number of other rotating storms, squall lines, and microburst-producing storms (all of which were presumably severe or nearly so) occurred in environments with much lower CAPE values in Keenan and Carbone’s study. Interestingly, even the observed Darwin soundings on which WG09 based their tropical simulations (bottom section of Table 1) possess much less CAPE than the WG09 model soundings.

Since WG09 claim that their results have some degree of general applicability for the tropics, it is also worthwhile to investigate CAPE values for other tropical locations (top section of Table 2), including the western Pacific warm pool, which Riemann-Campe et al. (2009) have shown to be one of the locations with consistently highest CAPE anywhere on the earth (e.g., their Fig. 1). None of the studies summarized in Table 2 have CAPE values approaching those used by WG09, with the exception of a few of the highest outliers from the tropical Atlantic dataset of Williams and Renno (1993). In trying to show that their results were not specific to Darwin, WG09 also based some of their simulations on the tropical soundings from Colon (1953) and Jordan (1958). The CAPE values of those soundings (bottom section of Table 2), based on the thermodynamic profiles actually given in those papers, were a factor of 2–2.5 lower than what WG09 utilized. In short, by almost any standard, the CAPE values in the WG09 simulations are extreme.
The problem in comparing the tropical versus mid-latitude results of WG09 is twofold because although their tropical CAPE values are on the very high end of the distribution, their corresponding midlatitude CAPE values are not. Rasmussen and Blanchard (1998, their Figs. 9 and 10) show 6 tornado cases (out of 51 total), 5 nontornadic supercell cases (out of 119 total), and at least a dozen nonsupercell thunderstorm cases with CAPE exceeding 3000 J kg\(^{-1}\)). Thompson et al. (2003) performed a similar study using model analyses (instead of proximity soundings) and found that the 75th percentile value of CAPE\(^2\) for their significant tornado cases was 3093 J kg\(^{-1}\) (their Fig. 6). In other words, while WG09 used extreme outliers in terms of CAPE for their tropical soundings, more than 25% of the Thompson et al. (2003) significant tornado cases in the United States had more CAPE than the highest value (2917 J kg\(^{-1}\)) WG09 tested for their midlatitude simulations. In an excellent review summarizing what is known about severe weather in the tropics, Barnes (2001, p. 421) states that “CAPE, for most of the undisturbed deep tropics, is 1000–2000 [J kg\(^{-1}\)] ... not as much as the extreme environments for [severe storms] over the U.S. Midwest.” The tropical soundings used by WG09 are unreasonable both in terms of the simple magnitude of their CAPE and in terms of their comparative relationship to WG09’s midlatitude soundings.

The reason for the excessive tropical CAPE values in the WG09 study becomes readily apparent from studying their Fig. 2: WG09’s approach to creating the profiles in their initial model soundings appears to inflate their low-level water vapor mixing ratios significantly. Both soundings reveal a layer with constant potential temperature up through roughly 800 hPa, whereas the mixing ratio is constant only up to roughly 900–925 hPa, above which it falls precipitously. In a real atmospheric boundary layer, if a ~2-km-deep adiabatic convective boundary layer is observed, then the moisture will generally be mixed through a similar depth. As shown here in Fig. 1, the actual observed soundings from Darwin on the three days that WG09 selected had low-level structures that were completely unlike what WG09 used for their numerical experiments. These morning soundings appear, at best, to support a well-mixed low-level mixing ratio of approximately 16 g kg\(^{-1}\). The Colon (1953) and Jordan (1958) soundings similarly support much lower mixing ratios than the 20 g kg\(^{-1}\) that WG09 used; the Colon sounding has a surface mixing ratio of 18.8 g kg\(^{-1}\)

\(^{2}\) Moreover, Thompson et al. (2003) computed mixed layer CAPE, which is generally smaller than the surface-based CAPE.
Table 2. A summary of CAPE values for a variety of tropical locations, as gathered from previously published studies. The top section includes studies that reported a distribution of values for a large number of soundings. The bottom section includes two studies that produced mean composite soundings, which were used for some of the simulations of WG09. The abbreviated field programs are the Amazon Boundary Layer Experiment (ABLE), Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE), and Tropical Ocean and Global Atmosphere Coupled Ocean–Atmosphere Response Experiment (TOGA COARE).

<table>
<thead>
<tr>
<th>Study</th>
<th>Region</th>
<th>Time period</th>
<th>Values and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucas and Zipser (2000)</td>
<td>W. Pacific warm pool</td>
<td>Nov 1992–Feb 1993 (TOGA COARE)</td>
<td>“Most unstable” group of cases had mean near 1700 J kg(^{-1})</td>
</tr>
<tr>
<td>Ciesielski et al. (2003)</td>
<td>W. Pacific warm pool</td>
<td>Nov 1992–Feb 1993 (TOGA COARE)</td>
<td>Values clustered from 1200 to 1500 J kg(^{-1}), with few values exceeding 1800 J kg(^{-1})</td>
</tr>
<tr>
<td>Williams and Renno (1993)</td>
<td>Tropical Atlantic</td>
<td>Jun–Sep 1974 (GATE)</td>
<td>Mode near 2000 J kg(^{-1}), with few values exceeding 4500 J kg(^{-1})</td>
</tr>
<tr>
<td>Williams and Renno (1993)</td>
<td>South America</td>
<td>Jul–Aug 1985, Apr–May 1987 (ABLE)</td>
<td>Mode near 750 J kg(^{-1}), with few values exceeding 2500 J kg(^{-1})</td>
</tr>
<tr>
<td>Colon (1953)</td>
<td>Southwest tropical Pacific</td>
<td>Mean for Jun–Sep 1944–47</td>
<td>Calculated CAPE = 2758 J kg(^{-1}) (compared to WG09’s value of 5925 J kg(^{-1}))</td>
</tr>
<tr>
<td>Jordan (1958)</td>
<td>West Indies</td>
<td>Mean for Jul–Oct 1946–55</td>
<td>Calculated CAPE = 1898 J kg(^{-1}) (compared to WG09’s value of 5742 J kg(^{-1}))</td>
</tr>
</tbody>
</table>

with a 0–1-km mean value of 16.1 g kg\(^{-1}\), and the Jordan sounding has a surface mixing ratio of 18.1 g kg\(^{-1}\) with a 0–1-km mean value of 15.6 g kg\(^{-1}\). WG09 primarily interpret their storms’ outflow production in terms of hydrometeor loading, which in turn they see as being mainly slaved to the water vapor mixing ratio in the low levels. It is therefore unfortunate that WG09’s method for constructing the initial tropical soundings leads to unrealistically high surface mixing ratio values for their chosen surface temperatures. This problem, in turn, also entails unrealistically large amounts of CAPE.

A final concern is that WG09 claim that the idealized sounding of WK82 is a representative midlatitude sounding for severe weather. Many of the results of WG09 actually follow from the assumption that tropical convective environments are drier than midlatitude convective environments. While great credit is due to Weisman and Klemp for designing an analytical sounding that was suitable for producing a wide variety of convective modes in first-generation cloud models, the sounding is generally much moister than midlatitude severe weather soundings, especially in the continental United States. For example, it has been known since the pioneering work of Fawbush and Miller (1954) that a preponderance of U.S. tornadoes occur in air masses that are very dry immediately above the boundary layer–topping inversion (e.g., their Fig. 1). This is not unique to tornadoic environments, as the composite derecho sounding from Coniglio and Stensrud (2001) shows much the same signature (e.g., their Fig. 5). This recurring feature is associated with elevated mixed layers that are advected eastward from off of the dry high terrain in the western and southwestern United States (e.g., Carlson and Ludlam 1968).

As shown in this section, WG09’s tropical soundings have unrealistically high values of both CAPE and low-level mixing ratio, in contrast to which their midlatitude soundings have more typical values of CAPE but excessive middle tropospheric humidity. If a simulation using a typical tropical sounding with 2000 J kg\(^{-1}\) of CAPE were compared on even footing with a simulation using a representative midlatitude continental sounding that also had 2000 J kg\(^{-1}\) of CAPE, it seems unlikely that the resulting processes (particularly, the outflow strength) would be as dramatically different as what the study of WG09 depicts.

4. Comments on WG09’s model configuration and a simple demonstration

In addition to their problematic initial soundings, WG09 primarily use an initial warm bubble trigger that is very warm, a configuration that favors the production of comparatively strong outflow. In turn, this propensity for stronger outflow further pushes WG09’s simulations toward the tipping point whereby outflow production overwhelms the tendency for storm splitting. To try to assess the impact of the initial thermal’s strength, and to demonstrate the impact of very large CAPE on outflow production, I performed a simple test.

a. Model configuration for demonstration simulations

The present experiment used the “Cloud Model 1 (CM1; Bryan and Fritsch 2002), version 1.12. This same model is the basis for most of WG09’s primary results. To isolate the impacts of the thermal upon outflow production, the tests incorporated a resting base state.
The model configuration was the same as what WG09 reported in their section 2. The “control” simulations used the WK82 sounding with a surface mixing ratio of 14 g kg\(^{-1}\) (giving CAPE of 2037 J kg\(^{-1}\)), which was the middle of the three midlatitude soundings used by WG09. The microphysical parameterization was Kessler’s (1969) warm rain scheme, which was used in most of WG09’s main simulations (i.e., their section 3a). Since WG09’s primary results and my comments concern the role of initial outflow production, the present simulations were run for only 1 h.

WG09 claimed that “no qualitative differences were found” when they tested the sensitivity of their experiments to the strength (i.e., temperature perturbation) of their initial bubble trigger (which ranged from +2 to +8 K). This is surprising given that some of the prime differences between WG09’s tropical and midlatitude results occur as a result of outflow production early in

FIG. 1. Skew-\(T\)–log-\(p\) diagrams for the three Darwin soundings upon which WG09 based some of their tropical simulations: (a) 20 Nov 2001, (b) 17 Dec 2004, and (c) 14 Nov 2005, all at 0000 UTC. The 16 g kg\(^{-1}\) saturation mixing ratio line (discussed in the text) is darkened.
their simulations. Within a fixed environment, a +8-K initial bubble temperature perturbation entails much greater buoyancy than a +2-K initial bubble temperature perturbation; this, in turn, leads to much larger upward velocities (in the case of the +8-K bubble) and much greater initial precipitation production. It is curious then that the “Bryan” simulations (using the CM1), which form the majority of the results reported by WG09, used an initial warm bubble with an 8-K temperature excess. This is far in excess of what is needed to reliably trigger long-lived convection in the WK82 sounding.\textsuperscript{3}

In the present experiments, the initial bubble was alternately given a temperature excess of 8 K (WG09’s default value) and then 2 K. The bubble had the same initial dimensions and vertical position as what was reported in WG09’s Table 2. The pair of experiments was then performed again using a surface mixing ratio of 18 g kg\textsuperscript{-1} (giving CAPE of 4457 J kg\textsuperscript{-1} in the WK82 sounding).

Because there was no mean flow or vertical wind shear in the present tests,\textsuperscript{4} an axisymmetric model formulation was used to save on computations. The radial size of the axisymmetric grid was 100 km, so the initial outflow production was insensitive to the exterior lateral boundary. In short, in the present simulations an initial axisymmetric updraft develops from the warm bubble, precipitation forms, and an axisymmetric outflow develops and spreads outward along the surface. This captures the essential processes associated with the initial outflow formation and casts it as a function of the warm bubble’s strength and the CAPE of the initial model sounding.

\textbf{b. Results and discussion}

As summarized in Table 3, the present experiments show that either increasing the environmental CAPE or increasing the temperature excess of the initial warm bubble produces the following effects: stronger initial updrafts (column d), greater total upward mass flux (column e), greater liquid water content and hydro-meteor loading (column f), and greater total mass of evaporated rain (column g). The initial updraft speeds for the +8-K simulations may be surprising, but they are actually quite close to the theoretical maximal updraft speeds for undiluted parcels based on the conventional relationship of \( w_{\text{predicted}} = \sqrt{2 \text{CAPE}} \) (for CAPE = 2037 J kg\textsuperscript{-1}, \( w_{\text{predicted}} = 64 \text{ m s}^{-1} \); for CAPE = 4457 J kg\textsuperscript{-1}, \( w_{\text{predicted}} = 94 \text{ m s}^{-1} \)), and these theoretical values do not even include the bubble’s additional 8-K temperature excess. Notably, WG09’s values for \( w_{\text{max}} \) are somewhat lower than this (e.g., their Table 3).

Based on the appearance of the output in their Figs. 3–5, this could be because WG09’s simulations are overly diffusive. But regardless of whether their simulations use too much artificial diffusion or just enough (often beauty is in the eye of the beholder), this should not fundamentally alter the basic run-to-run sensitivities of initial storms to CAPE and bubble magnitude.

The interpretations of WG09 hinge on the notion that tropical thunderstorms produce copious outflow so quickly that the outflow overwhelms the storm-splitting process; for this reason, it is useful to focus on several metrics that are accumulated or averaged over the first hour (Table 3). Such integrated quantities are robust because they allow for the fact that after production of the initial updrafts and downdrafts, the temporal behavior (e.g., timing of maxima and minima) varies somewhat from simulation to simulation. The accumulated downdraft and outflow production must be directly

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
(a) & (b) & (c) & (d) & (e) & (f) & (g) \\
WK82 surface & CAPE & Bubble & Initial max \( w \) & Total upward mass flux & Mean liquid water & Total rain evap \\
\( q_s \) (g kg\textsuperscript{-1}) & CAPE (J kg\textsuperscript{-1}) & \( \theta \) (K) & (m s\textsuperscript{-1}) & (\( \times 10^{12} \) kg) & content (\( \times 10^{13} \) kg) & (\( \times 10^{12} \) kg) \\
\hline
14 & 2037 & 2 & 25.1 & 1.5 & 0.3 & 0.9 \\
14 & 2037 & 8 & 64.7 & 9.0 & 3.5 & 6.2 \\
18 & 4457 & 2 & 72.9 & 30.6 & 15.3 & 15.1 \\
18 & 4457 & 8 & 90.7 & 36.9 & 21.6 & 22.4 \\
\hline
\end{tabular}
\caption{Metrics quantifying the initial convective intensity produced by the idealized simulations described in section 4a. The columns are (a) the initial surface mixing ratio in the WK82 sounding; (b) the CAPE of the surface-based parcel in that sounding; (c) the potential temperature excess of the initial warm bubble trigger; (d) the maximal upward velocity produced in the first updraft that develops in each simulation; (e) the total mass fluxed upward during the entire 1-h simulation; (f) the 1-h average of the minute-by-minute value of domain-integrated liquid water mass; and (g) the total mass of rain evaporated during the entire 1-h simulation.}
\end{table}

\textsuperscript{3} WK82 used a 2-K warm bubble for their simulations, noting that it was the minimal value necessary to initiate convection in their matrix of CAPE-shear tests, and that increases in the bubble’s magnitude produced “a pronounced quantitative effect on the initial storm growth.”

\textsuperscript{4} WG09 show (their Fig. 7) a monotonic decrease in outflow strength with increasing vertical wind shear, but even so, their highest CAPE (tropical) simulations continue to produce the strongest outflow. To exploit the computational affordability of the axisymmetric framework, simulations with vertical shear were not performed here.
Table 4. Metrics quantifying the outflow produced by the idealized simulations described in section 4a. Columns (a)–(c) are identical to those in Table 3. The remaining columns are (d) the 1-h average of the minute-by-minute minimum value of surface potential temperature perturbation; (e) the 1-h average of the minute-by-minute maximum value of surface horizontal wind perturbation; (f) the time of initial appearance of a surface gust front (as identified by a coherent, outward-moving gradient in both $\theta'$ and $u'$); and (g) the gust front speed [computed 12 min after the time in (f), just as WG09 did].

<table>
<thead>
<tr>
<th>(a) WK82 surface $q_v$ (g kg$^{-1}$)</th>
<th>(b) CAPE (J kg$^{-1}$)</th>
<th>(c) Bubble $\theta^*$ (K)</th>
<th>(d) Outflow surface min $\theta'$ (K)</th>
<th>(e) Outflow surface max $u$ (m s$^{-1}$)</th>
<th>(f) Time of gust front appearance (min)</th>
<th>(g) Gust front speed (m s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>2037</td>
<td>2</td>
<td>$-0.5$</td>
<td>2.3</td>
<td>35</td>
<td>2.3</td>
</tr>
<tr>
<td>14</td>
<td>2037</td>
<td>8</td>
<td>$-1.6$</td>
<td>6.0</td>
<td>22</td>
<td>4.5</td>
</tr>
<tr>
<td>18</td>
<td>4457</td>
<td>2</td>
<td>$-1.5$</td>
<td>5.3</td>
<td>32</td>
<td>3.8</td>
</tr>
<tr>
<td>18</td>
<td>4457</td>
<td>8</td>
<td>$-2.0$</td>
<td>7.8</td>
<td>19</td>
<td>5.0</td>
</tr>
</tbody>
</table>

linked to both hydrometeor loading and evaporation of rain mass, both of which are strongly a function of CAPE (Table 3). This illustrates a fundamental problem with the extreme CAPE values in WG09’s tropical soundings. And further, it is clear from Table 3 that using a +8-K warm bubble also substantially increases both the hydrometeor loading and the total evaporative cooling. This illustrates a fundamental problem with WG09’s experimental design.

Because the integrated/averaged metrics in Table 3 are one-step removed from the actual surface outflow itself, it is worth assessing several other metrics to summarize the initial outflow’s intensity (Table 4). As summarized in Table 4, the present experiments show that either increasing the environmental CAPE or increasing the temperature excess of the initial warm bubble produced the following effects: colder surface outflow on average (column d), stronger outflow winds on average (column e), an earlier onset of the surface gust front (column f), and a correspondingly faster spreading of the surface outflow (column g). The values for outflow potential temperature (Table 4, column d) and wind perturbation (Table 4, column e) may seem somewhat unimpressive, but this is because they are averaged over the entire hour-long simulation (again, to account for timing differences among simulations). The analyses of WG09 instead relied more heavily on the onset time and instantaneous speed of the outflow. In the present experiments, such metrics (Table 4, columns f and g) also confirmed the outflow’s basic sensitivities to the bubble strength and environmental CAPE.

The impact of excessive CAPE (as in WG09’s tropical soundings) seems evident from this simple experiment. One might reason, though, that an excessively strong initial thermal would impact both the tropical and midlatitude simulations equally (and therefore would not bias WG09’s conclusions). However, the linchpin to WG09’s interpretation is that storm splitting in the tropics is often interrupted by excessively rapid spreading of the initial outflow. Therefore, any model ingredient that moves the simulations closer to (or past) this threshold is questionable. As documented in Tables 3 and 4, the combination of a very strong thermal with the very high CAPE in WG09’s tropical simulations undoubtedly places them in the far upper end of the spectrum in terms of initial updraft strength and early outflow production.

5. Conclusions

I find the potential relationship between storm splitting and outflow production to be intellectually stimulating and worthy of further study. However, I am skeptical that the results of WG09 correctly describe a systematic difference between tropical and midlatitude convection. Their tropical environmental soundings had unrealistic low-level moisture profiles and unusually large CAPE, whereas their midlatitude environmental soundings had unusually high midlevel relative humidity. And, at least one aspect of WG09’s simulations (the very warm initial trigger) further predisposed their simulations toward rapid production of strong outflow, amplifying the purported process of outflow overwhelming the tendency for storm splitting.

Even if it turns out to be true that tropical convection requires larger amounts of vertical shear for storm splitting, I am not convinced that the study of WG09 has properly demonstrated the correct reasons that such a sensitivity exists in nature. WG09 were inspired by the challenges faced by severe weather forecasters in Darwin, Australia, whose anecdotes suggest that midlatitude severe weather indices do not perform as well as expected. This is an important gap in the knowledge base that...
should indeed be addressed. First, the specific shortcomings of the midlatitude indices should be carefully documented and quantified in terms of the recurring ways in which tropical and midlatitude storm environments differ from one another. At that point, a more realistic numerical study would then seem apt.

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