Comments on "Observational Analysis of the Predictability of Mesoscale Convective Systems"

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1. Introduction

Jirak and Cotton (2007, hereafter JC07) proposed a new index to assist in forecasting the development of mesoscale convective systems (MCSs). This "MCS index" is the summation of three components that are a function of the 1) "best" lifted index (LI), 2) 0–3-km shear vector magnitude (SVM), and 3) 700-hPa temperature advection (TAdv). JC07's study also reemphasized important aspects of MCS development, namely, the importance of the low-level jet (e.g., Junker et al. 1999) and low-level warm advection (e.g., Maddox and Doswell 1982) in the development and sustenance of MCSs. Their MCS index attempts to account for these important physical processes.

The use of indices has become ubiquitous in operational weather forecasting, especially in the realm of deep moist convection. However, indices easily can be misused and overused, as discussed by Doswell and Schultz (2006). Some indices have been developed arbitrarily, and others lack a robust physical foundation. This may be complicated further when multiple variables are combined into a single index. As a consequence, before operational forecasters can utilize indices to their potential advantage, they need a solid understanding of both how the indices were developed and the relative importance of their underlying components.

The intent of this comment is to consider the MCS index and its three components, and subsequently to use the findings as motivation for others—in training and operational roles—to investigate such indices before they transfer them to operations. This study was conceived as the MCS index was being tested for operational use at the Weather Forecast Office (WFO) in Rapid City, South Dakota (RAP). Although the results do not refute the MCS index per se, there is concern this index (and possibly others) may be misapplied using standard operational gridded datasets. It is ultimately shown that the MCS index, in its present form (JC07), is not suitable for operational forecasting.

2. Examination of the MCS index and its components

The MCS index (JC07) is computed by summing three components as follows:

$$\text{MCS index} = \frac{(-\text{LI} - 4.4\,^\circ\text{C})}{(3.3\,^\circ\text{C})} + \frac{(\text{SVM} - 11.5\,\text{m}\,\text{s}^{-1})}{(5\,\text{m}\,\text{s}^{-1})} + \frac{(\text{TAdv} - 4.5 \times 10^{-5}\,\text{K}\,\text{s}^{-1})}{(7.3 \times 10^{-5}\,\text{K}\,\text{s}^{-1})}, \qquad (1)$$

where the three variables (LI, SVM, and TAdv—defined above) have been transformed to "standard normal form" (having a mean of zero and a standard deviation of unity); the MCS index is unitless because of this normalization. JC07 derived the means and standard deviations using North American Regional Reanalysis (Mesinger et al. 2006) data with 32-km grid spacing for 383 MCS events. Various gridpoint data for each MCS event were extracted 6 h prior to MCS initiation at the location (i.e., grid point) of the subsequent −52°C cloud shield centroid at MCS initiation.

After the MCS index was coded according to Eq. (1) for the Advanced Weather Interactive Processing System (AWIPS) at WFO RAP, the individual variables were overlaid on the MCS index to view the relative importance of these three constituents. Using an arbitrary convective event with standard operational gridded

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datasets, it was found during testing that the TAdv contour pattern displayed notable similarity to that of the MCS index, especially for the relatively large absolute TAdv values (e.g., cf. north-central South Dakota in Fig. 1). This behavior was not unique to this one event; indeed, it was found with 20 other arbitrarily selected archived convective events from 5 May to 17 July 2007.

To understand the underlying cause(s) of this unexpected behavior, the three components of the MCS index were computed for an operationally viable range of conditions (Table 1). This range spans most values observed during typical convective situations, but it does not necessarily capture all extreme values. Moreover, this range is valid for operational datasets with output grid spacing of 13, 40, and 80 km. Although TAdv range—one measure of variability—increases as grid spacing decreases from 80 to 13 km (because TAdv is a derivative), extreme values of $\pm 97.2 \times 10^{-5}$ K s^{-1} (± 3.5°C $^{-1}$) were noted in testing with 80-km grids.

It is clear that the TAdv range from JC07's dataset (boldface region of TAdv in Table 1) represents only a small portion (<40%) of the typical operational range.[1] JC07's TAdv values for a range of ± 2 standard deviations (σ) from the mean (from -10.1×10^{-5} to $+19.1 \times 10^{-5}$ K s^{-1}, or $-0.36°$ to $+0.69$°C h^{-1}), which represent 95% of a Gaussian distribution, would be considered only weak to modest by operational standards. The operational range of TAdv values in Table 1 arguably could be even greater (e.g., from $-2.0°$ to $+3.0$°C h^{-1}), making this discrepancy even more apparent.

The divergence among the three components becomes more evident when they are plotted together (Fig. 2). Although the component values for LI and SVM follow similar trends, the component values for TAdv (dotted line in Fig. 2) cover a range that is more than 2.2 times as large. It is possible that TAdv is relatively more important than the LI and SVM variables in forecasting MCS development; however, the Heidke skill score results presented in JC07 (their Table 8) indicate that SVM is more important than TAdv in this regard. It is thus unreasonable to expect the TAdv component values to rise more rapidly and to be larger than those for the SVM (as in Fig. 2).

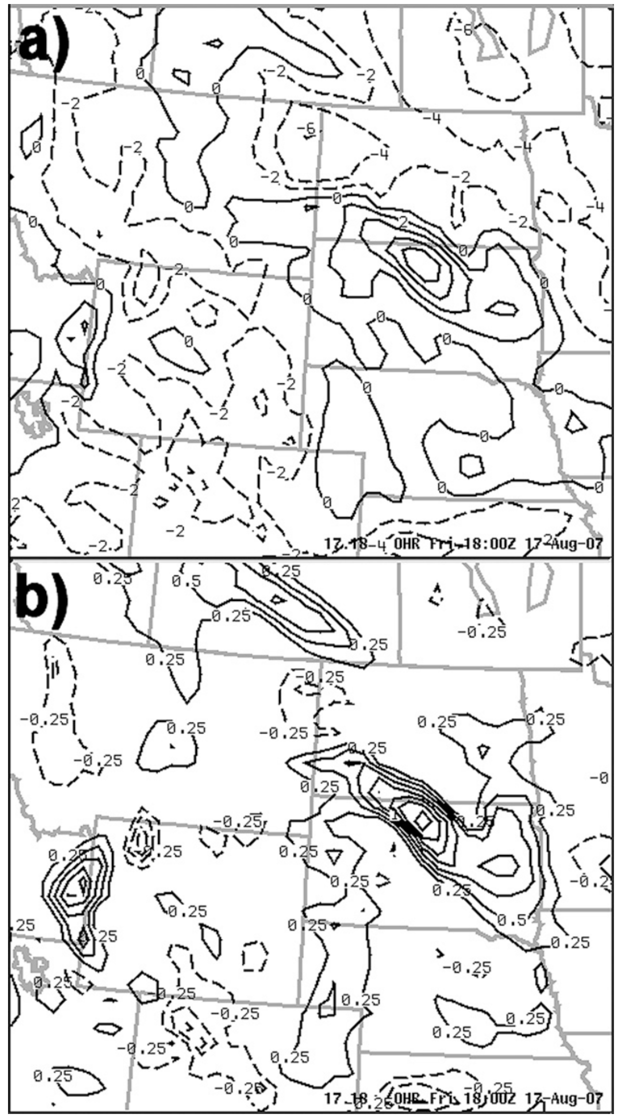

FIG. 1. Plot of the (a) MCS index and (b) 700-hPa TAdv valid at 1800 UTC 17 Aug 2007 from the 40-km RUC. Contour intervals are 2 for the MCS index (dashed negative) and 0.25°C h^{-1} for TAdv (dashed indicates negative; zero contour is omitted).

JC07 presented MCS index values that range mostly from -4 to $+4$ (e.g., refer to their Figs. 12 and 14–18). By way of comparison, if the component values in Table 1 reached their extremes concurrently, the MCS index values would range from -8.9 to $+12$. What is more, MCS index values from -20 to $+17$ were found during testing with the 20 aforementioned cases using Rapid Update Cycle (RUC) model output on a 40-km grid; Fig. 1 reveals MCS index values in excess of $+8$. Hence, the undue weight given to the TAdv component—by virtue of the nature of standard operational gridded datasets—can seriously inflate the MCS index,

[1] The LI and SVM operational ranges, on the other hand, appear to be in reasonable agreement with the ranges from JC07. Because the LI was measured 6 h prior to MCS initiation proximate to the subsequent MCS, it is understandable that it would be biased toward negative values (Table 1). However, not too far removed from this point (e.g., toward the cold side of a nearby surface frontal zone), LI values in excess of $+10$ have been observed (e.g., Colman 1990).

TABLE 1. Ranges and corresponding values for the three components of the MCS index; the three components are summed to produce the MCS index. Ranges for the "best" lifted index (LI), 0–3-km shear vector magnitude (SVM), and 700-hPa temperature advection (TAdv) are based on reasonably observed values in operations. Boldfaced values represent the range of ±2 σ from the mean using JC07's dataset. Note that two different units of TAdv are given: one is the standard mks version (10^{-5} K s^{-1}) and the other (°C h^{-1}, italicized) is used operationally at WFO RAP. The reasonable operationally observed lowest component values (−2.2, −2.3, and −4.4) yield an MCS index of −8.9 (first row of data) and the highest component values (2.3, 2.7, and 7.0) yield an MCS index of +12.0 (last row of data).

LI (°C)	LI component	SVM (m s^{-1})	SVM component	TAdv (10^{-5} K s^{-1}, °C h^{-1})	TAdv component
3.0	−2.2	0.0	−2.3	−27.8, *−1.0*	−4.4
2.5	−2.1	0.8	−2.1	−25.0, *−0.9*	−4.0
2.0	**−1.9**	**1.7**	**−2.0**	−22.2, *−0.8*	−3.7
1.5	**−1.8**	**2.5**	**−1.8**	−19.4, *−0.7*	−3.3
1.0	**−1.6**	**3.3**	**−1.6**	−16.7, *−0.6*	−2.9
0.5	**−1.5**	**4.2**	**−1.5**	−13.9, *−0.5*	−2.5
0.0	**−1.3**	**5.0**	**−1.3**	**−11.1,** *−0.4*	**−2.1**
−0.5	**−1.2**	**5.8**	**−1.1**	**−8.3,** *−0.3*	**−1.8**
−1.0	**−1.0**	**6.7**	**−1.0**	**−5.6,** *−0.2*	**−1.4**
−1.5	**−0.9**	**7.5**	**−0.8**	**−2.8,** *−0.1*	**−1.0**
−2.0	**−0.7**	**8.3**	**−0.6**	**0.0,** *0.0*	**−0.6**
−2.5	**−0.6**	**9.2**	**−0.5**	**2.8,** *0.1*	**−0.2**
−3.0	**−0.4**	**10.0**	**−0.3**	**5.6,** *0.2*	**0.1**
−3.5	**−0.3**	**10.8**	**−0.1**	**8.3,** *0.3*	**0.5**
−4.0	**−0.1**	**11.7**	**0.0**	**11.1,** *0.4*	**0.9**
−4.5	**0.0**	**12.5**	**0.2**	**13.9,** *0.5*	**1.3**
−5.0	**0.2**	**13.3**	**0.4**	**16.7,** *0.6*	**1.7**
−5.5	**0.3**	**14.2**	**0.5**	**19.4,** *0.7*	**2.0**
−6.0	**0.5**	**15.0**	**0.7**	22.2, *0.8*	2.4
−6.5	**0.6**	**15.8**	**0.9**	25.0, *0.9*	2.8
−7.0	**0.8**	**16.7**	**1.0**	27.8, *1.0*	3.2
−7.5	**0.9**	**17.5**	**1.2**	30.6, *1.1*	3.6
−8.0	**1.1**	**18.3**	**1.4**	33.3, *1.2*	3.9
−8.5	**1.2**	**19.2**	**1.5**	36.1, *1.3*	4.3
−9.0	**1.4**	**20.0**	**1.7**	38.9, *1.4*	4.7
−9.5	**1.5**	**20.8**	**1.9**	41.7, *1.5*	5.1
−10.0	**1.7**	**21.7**	**2.0**	44.4, *1.6*	5.5
−10.5	**1.8**	22.5	2.2	47.2, *1.7*	5.9
−11.0	**2.0**	23.3	2.4	50.0, *1.8*	6.2
−11.5	2.2	24.2	2.5	52.8, *1.9*	6.6
−12.0	2.3	25.0	2.7	55.6, *2.0*	7.0

making it not much more than a proxy for TAdv when TAdv values exceed 25.0 × 10^{-5} K s^{-1} (0.9°C h^{-1}); this is an occurrence common to many convective events. For example, in a typical convective scenario (e.g., LI = −6, SVM = 15 m s^{-1}, and TAdv = 27.8 × 10^{-5} K s^{-1} or 1.0°C h^{-1}), the MCS index might be 4.4 (components 0.5 + 0.7 + 3.2, respectively; see Table 1), but with 73% of the contribution arising from TAdv. This has implications for the guidelines of the MCS index as well (JC07, their Table 10).

Why is the TAdv range not consistent between JC07's study and the operational datasets? First, it is possible the maximum values of TAdv are underrepresented in JC07 because only a point value was obtained for each of the 383 MCS events (see first paragraph of this section), and the maximum TAdv might not have corresponded to this location. Furthermore, this point value was obtained 6 h prior to MCS initiation, and this signal could have been weaker than at MCS initiation time. Second, any smoothing or compositing, if applied, might have affected the maximum values of TAdv in JC07's study; this certainly would have diminished the maximum TAdv values relative to what is observed using standard operational gridded datasets. Of interest, Cotton et al. (1989) noted that their composite maps were a product of much filtering, averaging, and interpolation, with only the strongest signals remaining. Nevertheless, their Fig. 7a showed a maximum TAdv of 26.2 × 10^{-5} K s^{-1} (0.94°C h^{-1}), which appears higher than the *point-based values* obtained from JC07. Moreover, this is an order of magnitude higher than is displayed in the composite maps of JC07 (~5.0 × 10^{-5} K s^{-1}; their Fig. 9a). It therefore appears that smoothing was not necessarily the cause for the small values of TAdv in JC07, relative to operational values, or even those from Cotton et al. (1989).

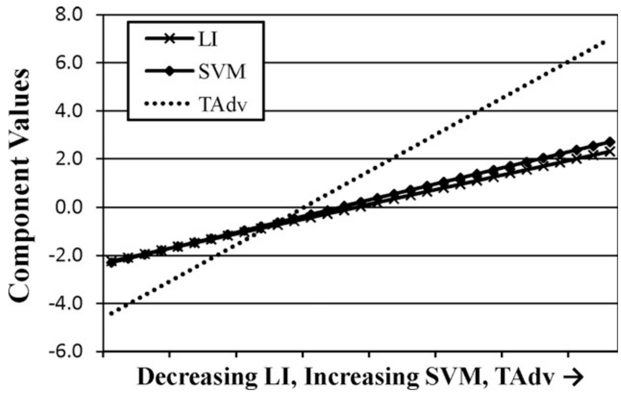

FIG. 2. Plot of the components of the MCS index according to Eq. (1) using the variable ranges given in Table 1. The ordinate displays component values for LI, SVM, and TAdv. The abscissa covers the ranges of LI (from $-3°$ to $+12°C$), SVM (from 0 to 25 m s^{-1}), and TAdv (from -27.8×10^{-5} to $+55.6 \times 10^{-5}$ K s^{-1}).

3. Conclusions and summary

Based on the above comments regarding JC07, the following conclusions are made:

1) The MCS index is not suitable for operations in its present form because it is dominated by the TAdv component when applied to standard operational gridded datasets. Not much additional value will be gained by viewing the MCS index on AWIPS (and likely other operational software platforms) than otherwise would be gained by viewing TAdv alone.
2) Individuals in training, and especially operational roles, should investigate new indices *before* implementing them in operations in order to determine their efficacy at producing desirable results. It may be that indices developed with nonoperational datasets will result in unintended consequences when applied to standard operational gridded datasets.

It likely was not the intent of JC07 to have TAdv overweighted in the MCS index using standard operational gridded datasets. Despite the conclusions presented here, the MCS index *might* be adapted for operations if the TAdv component is weighted appropriately. In the ideal case, Jirak and Cotton could recompute the mean and standard deviation to adjust the normalization for the TAdv component in Eq. (1), which appears to be the source of the problem. In the interim, a less desirable approach for operational purposes would be to derive a different weight for TAdv. For example, through testing it was found that if TAdv is divided by 2.5 before it is input into Eq. (1) then the MCS index produces a range of values that is consistent with JC07 and, furthermore, the TAdv component values are much closer to the values for SVM and LI (i.e., the slope of the dotted line in Fig. 2 changes to between the two solid lines). An additional consideration to this weighting would be for operational forecasters to create a ‘‘procedure’’ or ‘‘macro’’ whereby the MCS index is displayed simultaneously with the LI, SVM, and TAdv (such as in a four-panel display), thus affording the opportunity to compare the MCS index with its three constituents. This conforms to the spirit of JC07, who noted the MCS index should be used in conjunction with other information.

The importance of investigating and displaying other indices in a manner similar to that suggested here cannot be overstated for trainers and operational forecasters alike. In the case of the widely used significant tornado parameter (STP[2]; Thompson et al. 2003), as just an example, one could compute ranges of reasonable weights for the components involving mean-layer CAPE (MLCAPE), 0–6-km shear, 0–1-km storm-relative helicity (SRH), and mean-layer lifted condensation level (MLLCL) height. This process would reveal that the MLCAPE and SRH components have the relatively largest weights while the 0–6-km shear and MLLCL components have the relatively smallest weights; both the SRH and MLLCL components can be negative. The four constituent variables of the STP ideally should be viewed concurrently with the STP, analogous to what was proposed above for the MCS index, because the same value of an index can result from vastly different combinations of the input variables.

In summary, it is believed a multivariate index can have some utility for forecasters (e.g., highlighting areas of potential concern in short order) if the following three conditions are satisfied: 1) the variables for the index are physically related to the process being forecast, which appears to be the case for the MCS index; 2) the weighting factors and the mathematical formulation of the variables for the index are sound—a partial problem noted with the MCS index; and 3) forecasters understand what goes into the index and are aware of its strengths and limitations. The last step is arguably the most important, and this is why forecasters should always consult the constituent variables of any index to avoid the pitfalls of using the index. Last, it is suggested that *anyone* proposing an index should consider doing something similar to the methods discussed herein; this should not be left only to trainers and operational forecasters.

[2] This version of the STP is not used much on an operational basis. However, two revised versions of the STP are routinely plotted on the Storm Prediction Center ‘‘mesoanalysis’’ Web page (http://www.spc.noaa.gov/exper/mesoanalysis/).

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