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Evaluating a MCS Index in Southern Brazil for Two Brief Damaging MCSs

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Abstract Severe weather events associated with thunderstorms usually are extremely detrimental, damaging infrastructure and causing disorders in urban centers. One of the main causes systems of these events are the Mesoscale Convective Systems (MCS), that given its considerable territorial extension (above 100,000 km²) can cause widespread damage in a wide area. The aim of this study was to evaluate an alternative MCS index, constructed with the MCS South America climatology, and compare with the existing MCS index constructed with the American MCS climatology. Therefore, two MCSs that has generated severe weather in the southern Brazil (Rio Grande do Sul state - RS) and Uruguay were tested with the two indexes. It can be concluded that despite the proposed MCS index did not perfectly overlap the real observed MCSs, this showed a better performance compared with the existing MCS. It well represented the shape and location of the most intense cores of the MCSs and delimited a smaller area of probability of a MCS occurrence, close with respect to the real system observed.

Keywords MCS Index, Mesoscale Convective Systems, Severe Weather, Rio Grande do Sul, Uruguay

1. Introduction

Mesoscale convective systems are classified as a group of convective clouds that become organized in a single system, with an extensive structure at upper levels, also with cirriform cloud tops and a large area with contiguous precipitation of about 100 km at least in one direction [1].

These systems have begun to be studied deeply for the first time by Maddox [2], that analyzed a particular circular shape of these systems occurred in the USA. In South America, the study has initiated by Velasco and Fritsch [3] and has been extensively studied since then.

Other characteristic of these systems is that they can assume several shapes ranging from more linear to more circular. This is calculated from the ratio between their two orthogonal axes. The more circular MCSs are classified as Mesoscale Convective Complexes when also satisfy a size criteria for different temperature thresholds and minimum duration of 6 hours [3]. The more elongated MCSs when also satisfy the MCS criteria are classified as Persistent Elongated Convective Systems (PECS) [4].

Several methodologies have been used for the temperature threshold to detect MCSs through infrared satellite imagery, but that with -55°C temperature threshold for an minimum area of 100,000 km² presented a good result to detect deep convection in cloud tops observed at about 12 km height [5].

The contribution of the precipitation caused by these systems is very important in many areas of the globe, as the easter portion of subtropical South America [6], that has one of the highest incidences of MCSs all over the world [7-9]. Moreover, MCSs are largely associated with generation of severe weather [10-12].

Given the importance of such systems, many authors have proposed the use of thermodynamic indexes and construct a composed index of multiple variables to aid the prediction of convective developing and potential for severe weather [13-15] and one special for MCS that occurred in USA proposed by Jirak and Cotton (henceforward referred as Jirak index) [16].

Because of this close relationship with severe weather and their great occurrence in subtropical South America, the aim of this study was to test an alternative forecast product for MCS detection, based on the climatology of these systems in this region. For this test were chosen two MCSs cases occurred on October, 2015 in southern Brazil (Rio Grande do Sul state - RS) and Uruguay that caused severe weather.

2. Data and Methodology

To prepare this study were utilized satellite imagery data from GOES-13, channel 4 thermal infrared, with a spatial resolution of 4km x 4km in its sub-satellite point. These infrared images were fundamental to detect the configuration

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and the different stages of the MCSs by using the -55°C temperature threshold over an area of at least 100,000 km² and to compare the position of the system with the MCSs indexes tested here. These satellite imagery were obtained from CPTEC/INPE.

Also was utilized meteorological station data from INMET and Uruguayan press to obtain values of accumulated rainfall, wind gusts and severe weather reports.

Moreover, were utilized analysis and forecast (only for 3 hours later) data from Global Forecast System (GFS) [17] with spatial resolution of 0.25° x 0.25° to calculate the new proposed MCS index (explained in details in a forthcoming paper) for the different stages for the two MCSs.

Also was calculated the MCS Index obtained from the MCSs climatology in the USA by Jirak and Cotton [16] to compare with the alternative MCS index proposed here.

The two MCS indexes are composed by some representative variables observed in the earlier environment of the MCS configuration. It considers the average and the standard deviation for these variables, making the indexes dimensionless. The greater the value of it, the greater the possibility to configure a MCS in subsequent hours. These two indexes were calibrated specifically to differentiate environments that produce non-organized convective systems to those that configured a future MCS. In the proposed MCS Index the main changes were the adding of the vertical velocity variable, a lowering in the level of the temperature advection term and a deeper layer of vertical wind shear used.

3. Results and Discussions

The first MCS (15th October, 2015) reached more than 125,000 km² and passed across RS, causing severe weather reports over 27 cities in RS, like hail, heavy rainfall (until 93 mm in 10 hours) and intense winds (above 25 $m.s^{-1}$). This system lasted only four hours since it reached their minimum size criteria until diminish and merged with other MCS. This case was chosen due its complexity of the forecast, once it had a brief life cycle and an interaction with another MCS onto the rear of it. The infrared satellite image in the initiation stage of the MCS can be observed in Figure 1c. The MCS center is located over northeastern portion of RS (30°S, 50°W).

The performance of the two indexes can be visualized comparing the Figure 1a (Jirak index) and Figure 1b (new proposed index) with the satellite image for 2 hours and 30 minutes later. It can be seen that the two indexes indicated high probability of MCS occurrence over the northeastern RS, but the former index had a more scattered pattern than the latter. Moreover, the Jirak index pointed a very intense false alarm over the central Paraguay (24°S, 58°W) while the new proposed index indicated only low probability of development of a MCS in the later hours in this region. Over the northeastern Argentina, where a convective region can be observed in Figure 1c, the two indexes did not match very well, however the proposed index was more intense in the vicinities than the other.

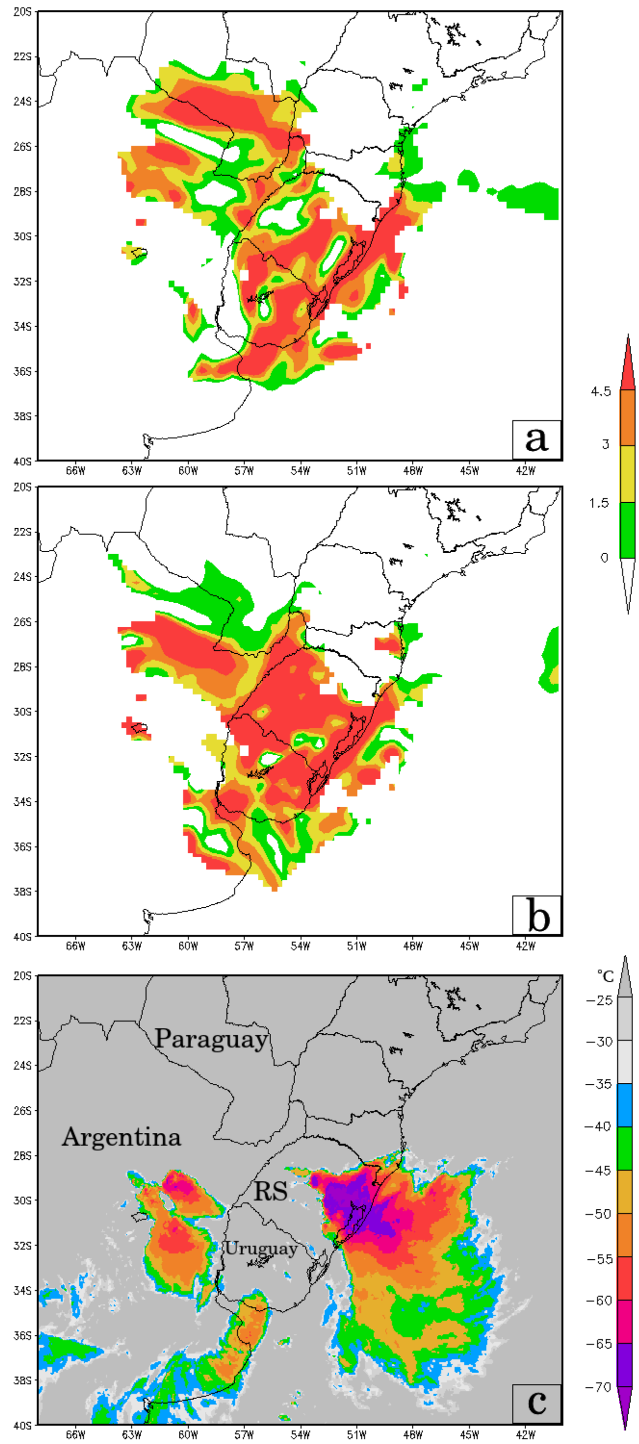

Figure 1. (a) MCS Index (Jirak et al., 2007) 2:30 hours earlier than the initiation stage; (b) alternative MCS Index 2:30 hours earlier than the initiation stage; (c) MCS occurred at 14th October 2015 at the initiation stage

The maturation stage (maximum size) of the first MCS can be visualized in the Figure 2. It can be observed a eastward displacement of the MCS, and the developing of another system to the west (Figure 2c). The Jirak MCS Index (Figure 2a) maintain the high probability of a MCS configuration over Paraguay while none convective system is situated there. Although Jirak index has detected a high possibility of occurrence in the middle of the MCS, the proposed index presented here showed a possibility area more restrict to the MCS and the convective systems in the vicinities (Figure 2b).

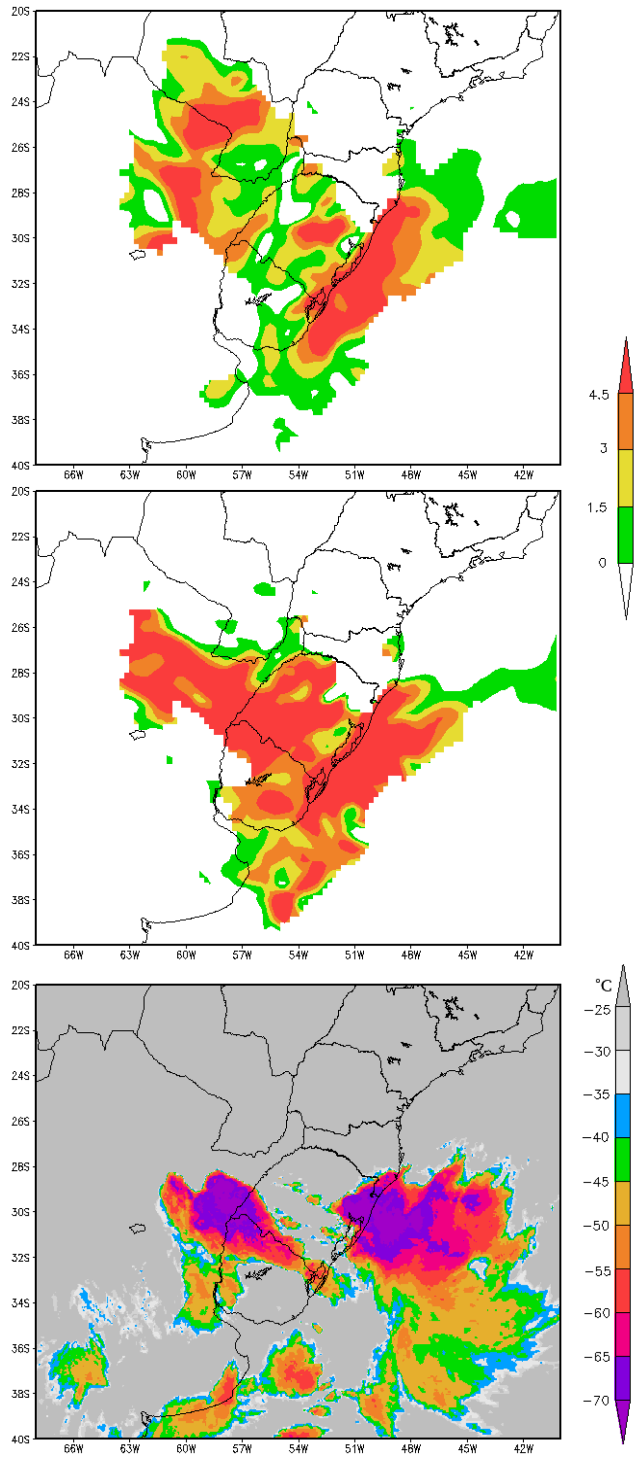

Figure 2. (a) MCS Index (Jirak et al., 2007) 0:30 hours earlier than the initiation stage; (b) alternative MCS Index 0:30 hours earlier than the initiation stage; (c) MCS occurred at 14th October 2015 at the maturation stage (maximum size)

Figure 3c illustrates the dissipation stage of the first MCS analyzed. The Jirak index (Figure 3a) has still maintained the high probability of occurrence of MCS over Paraguay, instead the proposed index do not showed anything for this region, as it was seen in the after hours. Over the MCS the Jirak index was less intense than the proposed index, and the latter show a more similar shape with the system. Both have detected reasonably well the development of th other MCS at the rear (30°S, 57°W - Figure 3c).

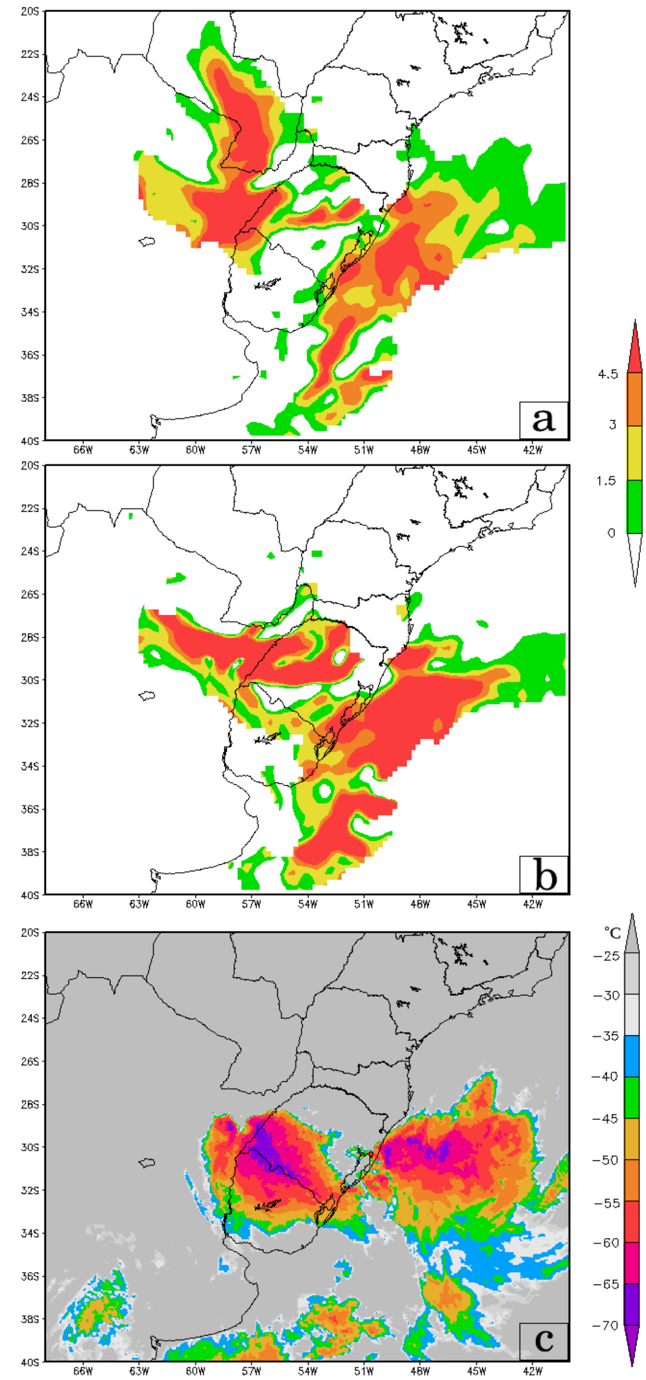

Figure 3. (a) MCS Index (Jirak et al., 2007) 0:30 hours earlier than the initiation stage; (b) alternative MCS Index 0:30 hours earlier than the initiation stage; (c) MCS occurred at 14th October 2015 at the dissipation stage

The second case studied occurred at 20th October, 2015 reaching more than 280,000 km², was responsible for some severe weather reports in RS and Uruguay, like heavy rainfall (almost 82 mm in 4 hours), intense winds (above 25 $m.s^{-1}$) and landslide. This MCS lasted a little more than the first (7 hours of life cycle). Differently of the former MCS analyzed, this one did not presented interaction with other system after its dissipation. At the initiation stage was observed over Uruguay (33°S, 55°W) with a more linear shape (Figure 4c).

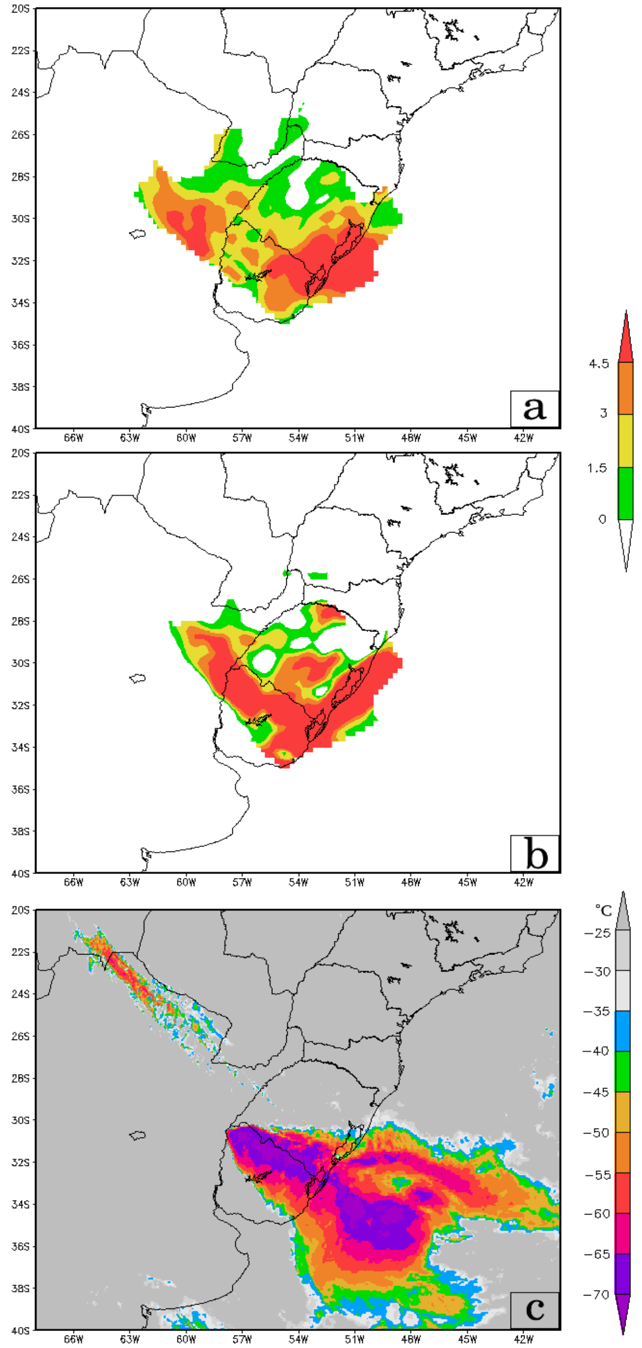

Figure 4. (a) MCS Index (Jirak et al., 2007) 1:00 hours earlier than the initiation stage; (b) alternative MCS Index 1:00 hours earlier than the initiation stage; (c) MCS occurred at 20th October 2015 at the initiation stage

The proposed index (Figure 4b) best represented this linear shape of the MCS than the Jirak index, that showed a segmentation of its maximum values, suggesting a future occurrence of two different systems (Figure 4c), that was no observed. In general, the two indexes did not show nothing where convection was not intense.

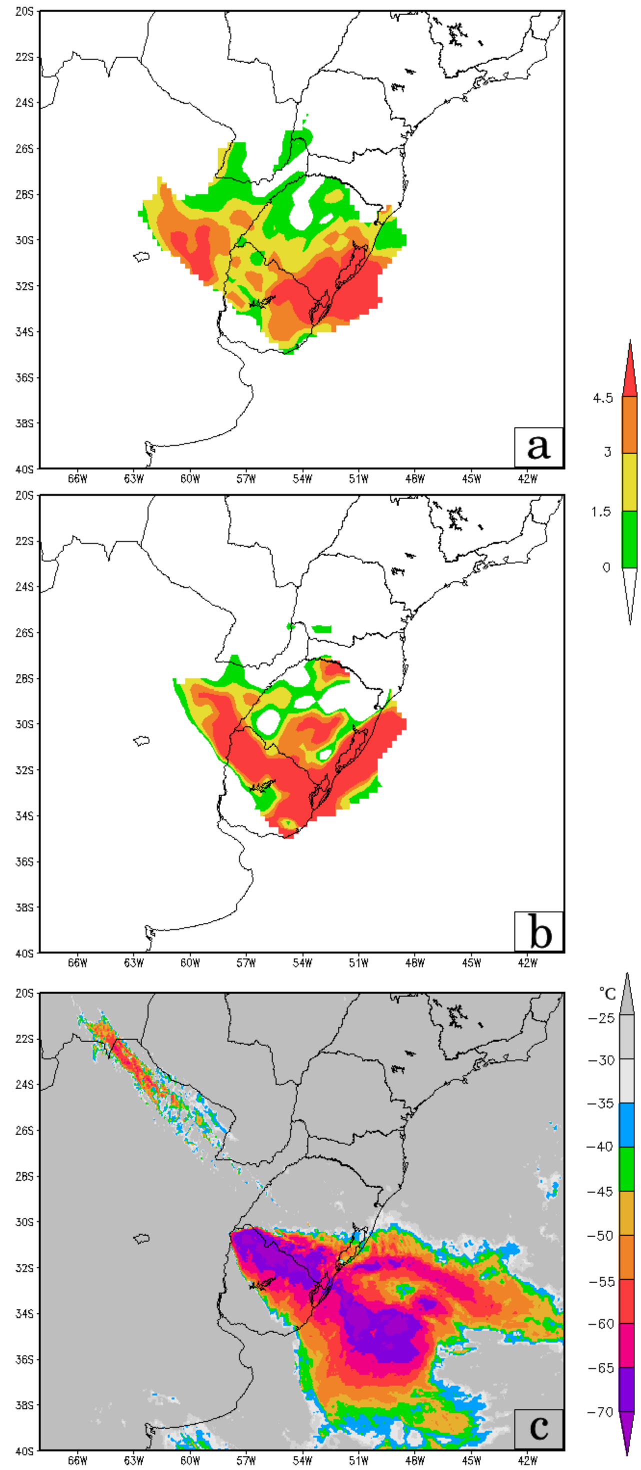

Figure 5. (a) MCS Index (Jirak et al., 2007) 2:30 hours earlier than the initiation stage; (b) alternative MCS Index 2:30 hours earlier than the initiation stage; (c) MCS occurred at 20th October 2015 at the maturation stage

Maturation stage was observed over the border between Brazil (Rio Grande do Sul state) and Uruguay also advancing to the Atlantic Ocean (33°S, 52°W – Figure 5c). The Jirak index still indicated two maximum values (Figure 5a) where only a single MCS has developed. Unlike that, the proposed index maintain its prediction of only one system observed with an unique maximum value centered close to the MCS observed, in addition to a more reliable shape with the MCS.

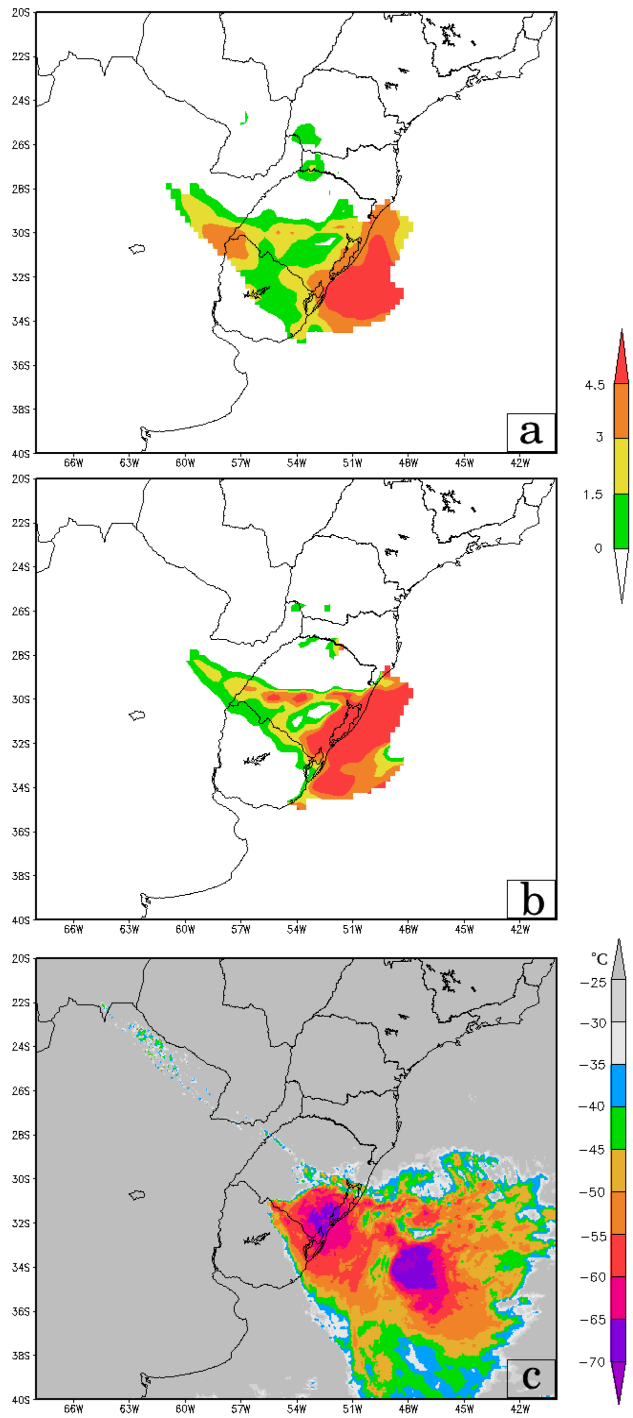

Figure 6. (a) MCS Index (Jirak et al., 2007) 2:30 hours earlier than the initiation stage; (b) alternative MCS Index 2:30 hours earlier than the initiation stage; (c) MCS occurred at 20th October 2015 at the dissipation stage

The last stage of the second MCS was illustrated in Figure 6c. It can be observed the beginning of a split into two and and consequently the minimum size criteria broken. This MCS, like the other one, migrated to east, with the average eastward motion expected for this latitude in the middle and upper levels of the atmosphere, without a redeveloping upstream as the MCSs analyzed by Anabor et al. [18] for this region.

The Jirak index dislocated to the east its maximum values compared with the observed MCS (Figure 6a), whereas the proposed index is more accurate, delimiting the higher possibility area with the observed system (32°S, 52°W). Over the border among Brazil (Rio Grande do Sul state), Argentina and Uruguay (30°S, 58°W) the Jirak index indicated a high probability of MCS occurrence, where nothing was observed in the next hours, whereas the proposed index indicated a minor chance.

4. Conclusions

This study discusses a possible operational use of an alternative MCS index developed with the MCS climatology of this region, showing a better performance compared with the existing MCS index, developed with the MCS cases over USA. This shows that for South America MCSs the temperature advection is more important in lower levels than the Americans MCSs, as well as a deeper shear wind layer and the inclusion of the vertical velocity parameter. The maximum values region of predictability resembled well with the shape of the convective cored of the MCSs observed hours later. The pointed region demarcated by the proposed MCS index was also smaller than the other index, facilitating the monitoring of possible MCS in subsequent hours.

This region of the globe have a high frequency of MCSs, and this new tool can improve the prediction of these systems, helping the centers of forecasting and decision makers to mitigate damage generated by SCMs.

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