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Analysis of distinct thresholds for CAPE and vertical wind shear covariates to discriminate severe weather environments in the La Plata Basin using ERA5 reanalysis

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Background and Motivation

Severe convective storms are responsible for producing hazardous weather phenomena that pose a threat to life and property in the La Plata Basin, located in subtropical South America.

A long-term official database of severe weather reports is not available for this region.

To conduct a preliminary analysis of the long-term variability of conditions favorable to severe storms in this region, atmospheric profiles were extracted from the ERA5 reanalysis (Hersbach et al., 2020) from 2013 to 2019 to compute atmospheric parameters that identify some of the necessary ingredients for the formation of severe deep convection.

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Methodology

Covariate quantities that describe regimes of severe weather environments within the parameter space comprising the convective available potential energy (CAPE) and deep-layer vertical wind shear (0–6-km bulk wind difference - BWD) were computed from atmospheric profiles obtained from the ERA5 (0.25°) gridded data at 6-hr intervals for a 7-year period (2013-2019) in the La Plata Basin.

This research follows the detection of days associated with conditions prone to severe weather (DSEV) based on the criteria described in the following four studies:

Authors	Covariate	Threshold	CAPE (Jkg^{-1})	BWD (ms^{-1})	Lapse Rate (Kkm^{-1})
A11	CAPE x $BWD^{1.67}$	68000	10	-	-
B03	CAPE x $BWD^{1.6}$	46800	100	-	6.5
G20	CAPE x $BWD^{1.67}$	25000	100	15	-
T09	CAPE x BWD	10000	100	5	-

Source: A11 = Allen, Karoly and Mills (2011); B03 = Brooks, Lee and Craven (2003); G20 = Glazer et al. (2020); T09 = Trapp, Diffenbaugh and Gluhovsky (2009).

For instance, in applying the A11 approach, if a given gridpoint at a given time displays CAPE x $BWD^{1,67}$ > 68000 and CAPE > 10 Jkg^{-1}, then an environment conducive to severe weather is flagged for that grid point and time. DSEV is counted at a gridpoint for any one day that exhibits at least one profile conducive to severe weather among the four profiles analyzed at 6-hr intervals.

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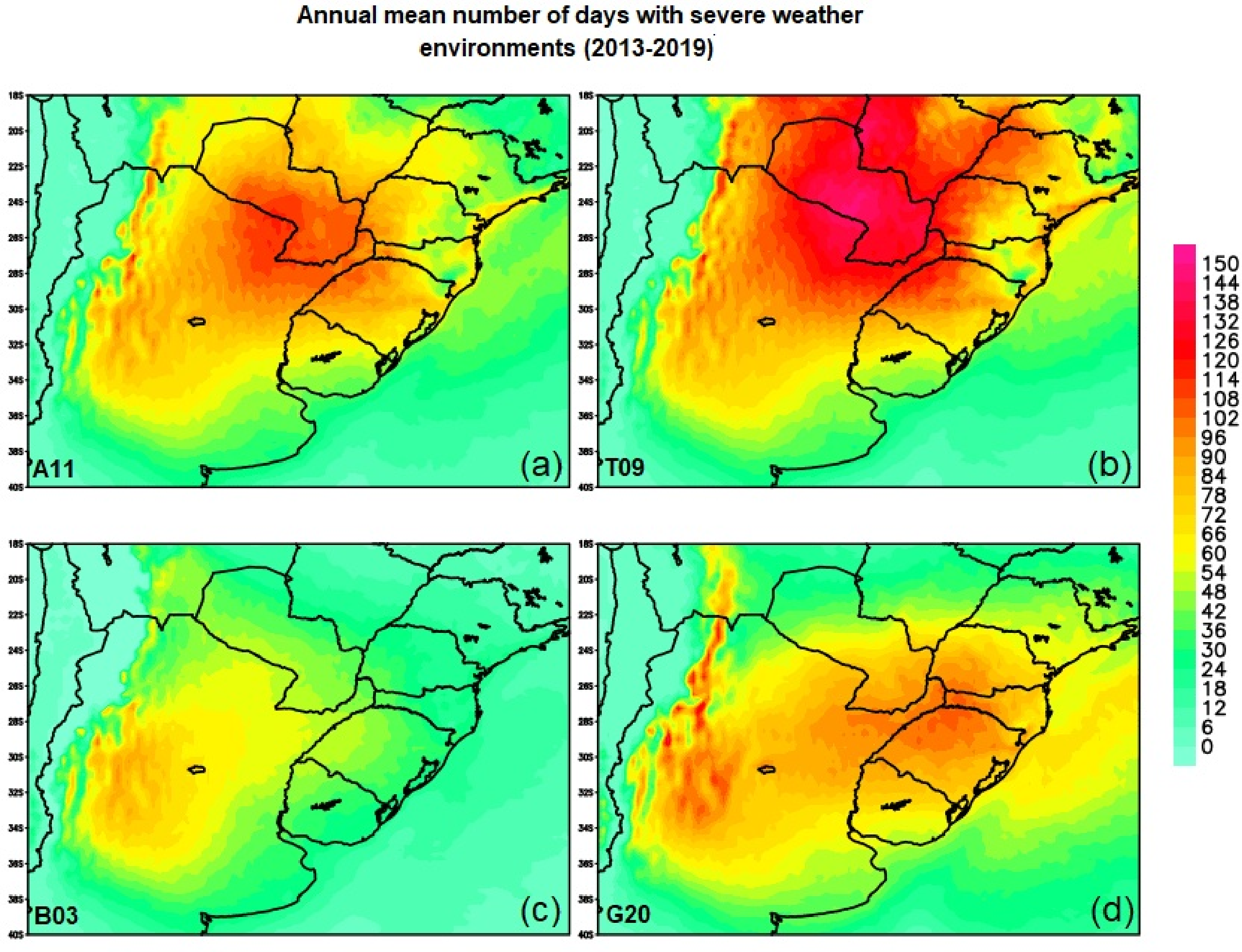
Results

Annual mean number of DSEV

- The DSEV flagged through A11, B03 and G20 criteria succeed in highlighting portions of the La Plata Basin and west-central Argentina that agree with previous observational studies in terms of highest frequency of severe deep convection (Zipser et al., 2006).

- T09 extends DSEV's highest frequency farther north, probably because of the lowest thresholding for CAPE x BWD.
- B03 provides the most conservative estimate of DSEV. It imposes a minimum threshold for lapse rate, which can explain west-central Argentina being particularly highlighted as a hot spot for severe weather.
- G20 shows a peak of DSEV over southern Brazil, including the triple border (Brazil-Argentina-Paraguay). As the lapse rates in southern Brazil tend to be weaker than those observed in west-central Argentina (Nascimento et al., 2016), this finding can be at least partially explained by the absence of a minimum cut-off value for the lapse rate in G20´s criteria.
- The high threshold applied to for BWD in G20 also seems to explain the highest frequency of DSEV being more restricted to higher latitudes as compared at least with A11 and T09.



Seasonal mean number of DSEV

Summer (DJF)

- The highest frequency of DSEV occurs in summer for all sets of criteria.
- B03 and G20 both emphasize the west-central sector of Argentina as the summer hot spot for severe convection, but G20 extends the hot spot slightly to the east.
- T09 exhibits a wider area of higher values of DSEV reaching lower latitudes, despite observational evidences that this sector becomes less prone to develop severe storms in summer (Nascimento et al., 2016).

Fall (MAM)

- DSEVs are reduced in all regions, except for the Brazil-Bolivia border in T09, where DSEVs remain high.
- B03 produces the lowest number of DSEVs in fall.
- Both A11 and G20 display a peak in west-central Argentina, but with two relative maxima: A11 in south-central Paraguay and G20 in the triple border Argentina-Brazil-Paraguay.

Winter (JJA)

- The winter exhibits the lowest DSEV frequency overall, in agreement with Cecil and Blakenship (2012) for hailstorms occurrence in southeastern South America.
- The highest DSEV values were found in G20 approach, particularly in southern Brazil and northeastern Argentina.

Spring (SON)

- Overall, DSEV experiences an increase in west-central Argentina, but remains lower than summer values.
- G20 produces a relative maximum of DSEV in southern Brazil, exceeding the respective values for this region in summer.

Diurnal Cycle of DSEV

- The peak of DSEV shifts eastward from 00Z-06Z (9 PM-3 AM) to 18Z (3 PM).
- One possible explanation is that in the nocturnal period it is the continental warm and moist advection performed by the northerly LLJ that accounts for an enhanced MLCAPE in the inland areas around the triple border region (Paraguay, Argentina and Brazil).
- In contrast, during the afternoon, when the northerly LLJ is generally weaker or absent, it is the widespread surface heating that accounts for higher MLCAPE.

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Summary

- Qualitatively, ERA5 data represent well the seasonal march of the hotspots for severe weather environments in the La Plata Basin comparing with previous results (Cecil and Blankenship, 2012; Matsudo and Salio, 2011; Nascimento et al., 2016).
- The shift of peak severe weather days seems to follow the climatological position of the subtropical jet (in DJF the Bolivian High “pushes” the subtropical jet poleward).
- Convective initiation is not considered in this analysis, so the DSEV maps most likely exhibit an overestimation of the actual number of severe weather days.

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Future Work and Acknowledgments

Future Work

- To develop a discriminant analysis that best highlight the CAPE-and-shear environments associated with severe weather in La Plata Basin utilizing a high-quality database of severe weather reports over a 3-year period.
- By accessing a longer period of ERA5 data (1980-2021) and with higher temporal frequency (at every 1 hr instead of at every 6 hr), a long-term analysis will be developed to assess if there is a trend in the time and/or space distribution of severe weather days within the La Plata Basin.

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- We also acknowledge enriching conversations with John T. Allen on feedback and suggestions throughout the research.
- ERA5 data (temperature, relative humidity, geopotential, pressure, U and V vectors) were downloaded from the European Centre for Medium-Range Weather Forecasts (ECMWF), Copernicus Climate Change Service (C3S) at Climate Data Store (https://cds.climate.copernicus.eu/).

LINK:

Abstract

Severe convective storms are responsible for producing hazardous weather phenomena, such as tornadoes, damaging winds and large hail, that pose a threat to life and property in many parts of the world, including the La Plata Basin in subtropical South America. In this preliminary study, covariate quantities that describe regimes of severe weather environments within the CAPE and vertical wind shear parameter space are computed from atmospheric profiles obtained from the ERA5 gridded data at 6-hr intervals for a 7-year period (2013-2019) in the La Plata Basin. These covariates are utilized to assess the magnitude of atmospheric ingredients known to favor the development of severe convective storms and to determine days with atmospheric conditions conducive to these storms. Following similar studies conducted for different regions around the world (Brooks et al., 2003; Trapp et al., 2009; Allen et al., 2011 and Glazer et al., 2020), distinct threshold values for the covariate quantity that multiplies mixed-layer CAPE and 0-6km bulk wind difference are assessed as discriminators for severe weather environments. An evaluation is conducted on how CAPE and shear covariates computed from ERA5 represent the seasonal march of severe weather hot spots in the La Plata Basin as compared to available short-term climatologies based on actual soundings, ground reports of severe weather, and remote sensing products.

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Session - Board Number

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