

TORNADOES IN SOUTHEAST SOUTH AMERICA: A MULTISCALE ENVIRONMENT ANALYSIS

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1) INTRODUCTION

Severe thunderstorms pose a great threat to the world population due to their inherent ability to cause extensive damage to property and devastating loss of human life. The exposure to this phenomenon has substantially increased during the last few decades mainly due to the increase in global population, which along with changes in extreme weather events caused by climate change, has raised monetary losses [Bouwer, 2019] and disaster risk [IPCC, 2012] worldwide. Tornadoes and tornadic storms have been extensively studied in the United States, where robust observing networks and advances in numerical weather prediction models can help anticipate the potential for tornado threat with acceptable accuracy [Brotzge and Donner, 2013; Brooks and Correia, 2018]. Other regions such as subtropical South America do not have dense observational networks (including ground-based radars until very recently) nor a routine collection and archival of severe weather reports, explaining in part the lack of studies and inadequate warning systems to anticipate and alert the population about these life-threatening events [Nascimento and Doswell, 2006]. The main goal is to describe the environments conducive to tornadic storms in southeast South America (SESA) at the mesoscale, synoptic, and planetary scales, including potential predictability sources in the tropics.

2) DATA AND METHODS

Given that no official severe weather report database (including tornadoes) exists in South America, a full search of digital newspaper archives, social media, and other online sources, was performed to create our database of tornadic events in subtropical South America. This effort resulted in a compendium of 74 tornadic events spanning Argentina, Paraguay, Uruguay, and southern Brazil, between 1991 and 2020 (Figure 1). In order to study the tornadic environment in the region, composites anomalies of the synoptic and large-scale environment were performed using hourly estimates from the ERA-5 dataset [Hersbach et al., 2020]. In addition, proximity soundings of every tornado were extracted employing ERA-5 data on model levels, which has a higher vertical resolution (137 vs 37 levels) and a representation of vertical levels following the terrain. Finally, an analysis of the Madden-Julian Oscillation (MJO) and its relationship with the environment prior to the development of tornadic storms was performed using the Real-time Multivariate MJO Index (RMM) from Wheeler and Hendon (2004).

3) RESULTS

The distribution of tornadoes maximized over the central plains away from the Andes Cordillera, though some events were close to secondary topographic features such as the Sierras

de Cordoba (SDC). Tornadoes were more frequent during the extended warm season (October through April), while winter (JJA) events were rare. Events were mostly concentrated during afternoon and evening hours, with very few during morning.

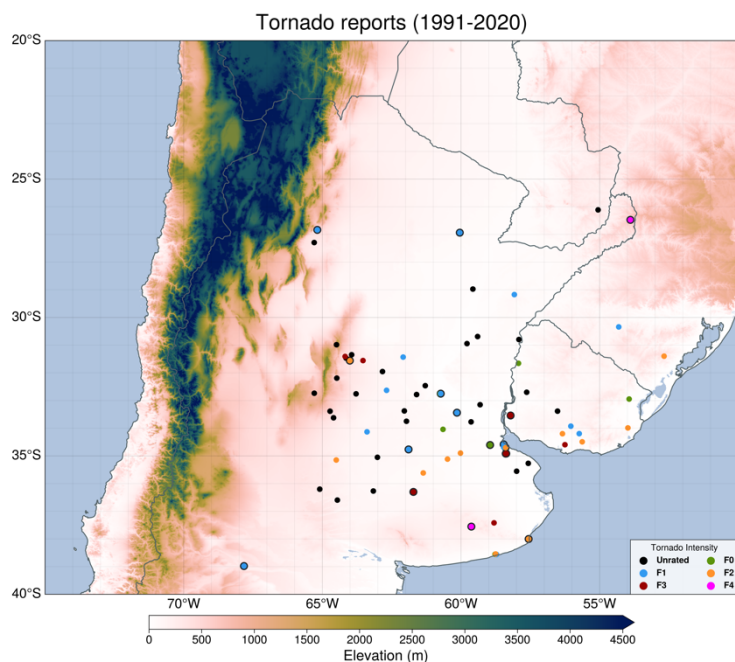


Figure 1. Selected tornado reports collected over subtropical South America (N=74). Color in dots represent estimated tornado intensity in the F-scale. Cases whose intensity was confirmed have a bold black edge. Terrain elevation (m) is shown in shading color.

Composites of several convective parameters were examined using the ERA-5 reanalysis dataset based on the location and time of occurrence of each event. Tornadoes generally occurred under a high shear (deep layer) - high CAPE (convective available potential energy) environment, with a hodograph showing counterclockwise rotation (i.e., backing in the Southern Hemisphere). The average mesoscale environment in the proximity of the reports (within 6 hours of the time of the event) showed an enhancement in tornadic parameters such as CAPE, low (0-1km) and deep (0-6km) layer shear (SH01 and SH06), and storm relative helicity (SRH), and a decrease in lifting condensation level (LCL) and convective inhibition (CIN). The values of these variables broadly reached levels previously found to be supportive of severe weather events in

the U.S., except for low-level circulation parameters (e.g., SH01 and SRH01) and CIN, which were weaker and stronger than expected, respectively. This gives some insights about the differences in tornado environments and frequency between both regions. Significant differences in low-level winds were also found between events closer to the higher terrain (e.g., Cordoba) and events further east; cases with SH01 < 5 m/s occurred mostly west of 62W, in the SDC vicinities, while cases with SH01 > 15 m/s took place mostly east of 59W, closer to the Atlantic coast.

From a synoptic scale perspective, the incursion of a midlatitude trough impinging on the Andes along with a strong mid to upper-level jet was evident prior to the development of tornadic storms. Lee cyclogenesis was triggered with low pressure crossing the mountain range, with subsequent formation of a northerly low-level jet that advects humid air from the Amazon to the central plains in Argentina. As a result, the environment was loaded with enough instability and vertical wind shear to support convective initiation and tornadic storms in the region.

This local synoptic pattern was supported by a large-scale wave-like pattern in the 250-hPa geopotential height anomaly field, showing a PSA-like appearance [O'Kane et al., 2017]. This pattern appeared to originate several days before tornadoes influenced the area, with an origin in the Maritime Continent and Indian Ocean, suggestive of forcing by enhanced tropical convection in these regions. Finally, the relationship of the tornadic events with the MJO was analyzed, showing that there was an overall preference for MJO phase 3 to be active during the previous two weeks before the tornadoes took place. This relationship could provide potential predictability of tornadic events in subtropical South America 1 to 2 weeks in advance.

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