Supercell Pre-Convective Environments in Spain: a dynamic downscaling of ERA-5 Reanalysis

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OBJECTIVES

1. Create a supercell upper-air environment climatology in Spain to know the average environmental conditions for supercell formation.
2. Improve the prediction of severe weather events in Spain.

INTRODUCTION

- ✓ Supercells are the less common type of thunderstorm, however it is responsible for most severe weather reports: hail greater than 5 centimetres, tornadoes and/or high-lightning activity (greater than 200 lightning per minute).
- ✓ During the last decades, several studies have analysed upper-air conditions that favour the development of severe thunderstorms (Rasmussen and Blanchard, 1998; Groenemeijer and van Delden, 2007; Taszarek et al., 2017). Most of them used proximity sounding data, but in last years studies developed with reanalysis data are more common due to increase in spatial and temporal resolution of models.

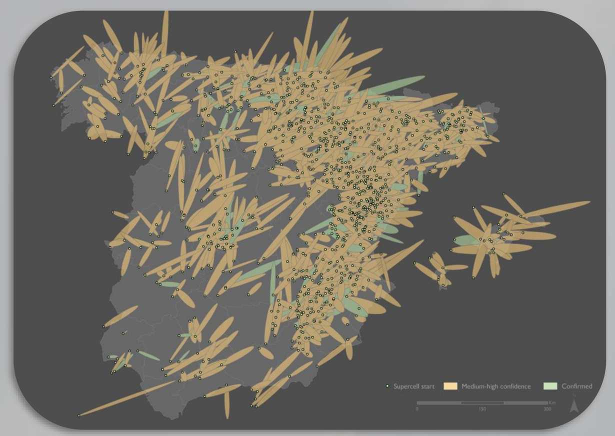
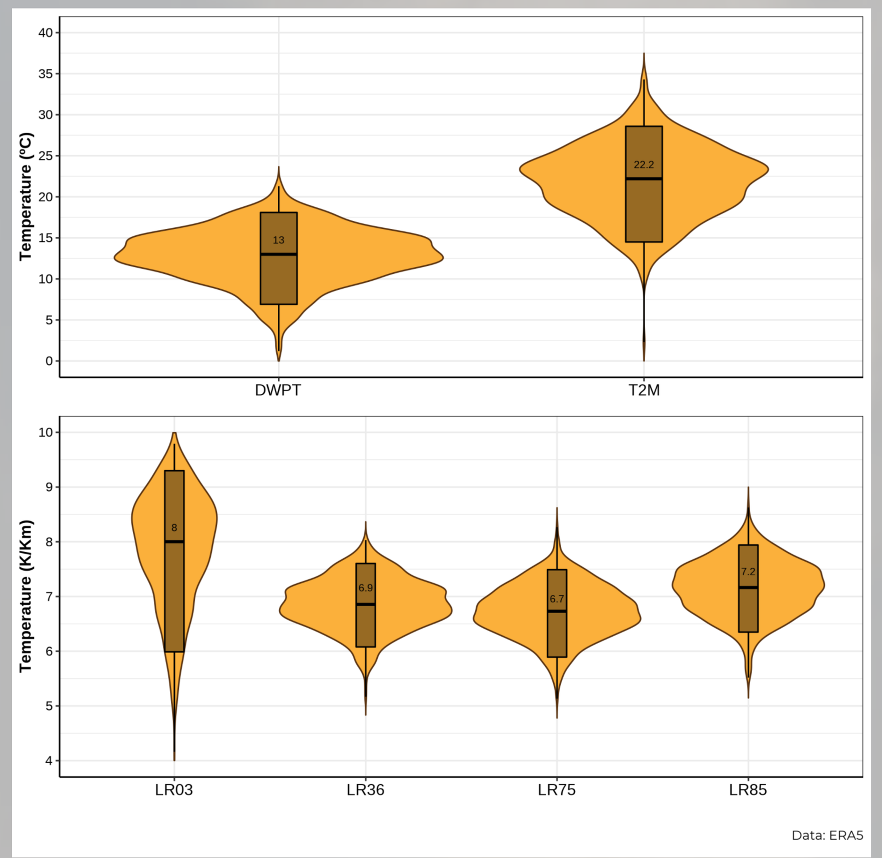


Figure 1: Supercells events for 2014-2019 period classified in Confirmed Supercells and Medium-High Confidence Supercells.

DATA

- ✓ Supercells events (703 events, in Figure 1) were retrieved from the Spanish Supercell Database (Martin et al., 2020) for the 2014-2019 period.
- ✓ 9-km, 54 pressure levels and 1-hourly temporal resolution ERA5 reanalysis downscaling by WRF-ARW model was used to obtain vertical temperature, dew point and wind profiles for each supercell event.
- ✓ The selection of the thermodynamic and kinematic parameters was based on similar previous studies (Rasmussen and Blanchard, 1998; Romero et al., 2007; Púcik et al., 2015; Rodriguez and Bech, 2020): Temperature at 2-meters (T2M) and Dew-Point Temperature (DWPT), Lapse-Rate (LR), Convective Available Potential Energy (CAPE), Wind-Shear (WS), Storm-Relative Helicity (SRH) and composite parameters (SCP, SHIP and STP).
- ✓ Calculations of the parameters were carried out using Sounding and Hodograph Analysis and Research Program in Python (SHARPpy) and data analysis in R.

Figure 2: Temperature and Dew-point (above) and LR75, LR85, LR03 and LR36 (bottom) violin and boxplots for supercells events. Whiskers extend from 25th and 75th percentiles to minimum and maximum values.



- ✓ T2M and DWPT have a wide range of values of all supercells events.
- ✓ Spanish supercells presents a similar DWPT than American supercells (10-12.5ºC), with a median of 13ºC.
- ✓ For T2M, the median in Spanish supercells is 22.2ºC.
- ✓ The values of T2M and DWPT denotates that the formation of supercells in Spain are concentrated in the Warm Season (from May to September).
- ✓ In general, the median of lapse-rates in Spanish supercells between 6.7 and 7.2 K/Km, but LR03 has a 8K/Km of median.
- ✓ The LR values shows that Spanish supercells developed close to superadiabiatic gradients (10 K/Km).

T2M: 25ºC DWPT: 16ºC LR03: 8ºC LR36: 6ºC LR75: 5.6ºC	SBCAPE: 1551 J/Kg MUCAPE: 1551 J/Kg MLCAPE: 923 J/Kg SBCIN: -6 J/Kg MUCIN: -6 J/Kg MLCIN: -33 J/Kg	WS01: 3.4 m/s WS06: 19.2 m/s WS08: 21.3 m/s EBWD: 19.5 m/s SRH01: 33 m2/s2 SRH03: 94 m2/s2	SCP: 2.9 SHIP: 0.4 STP: 0.0

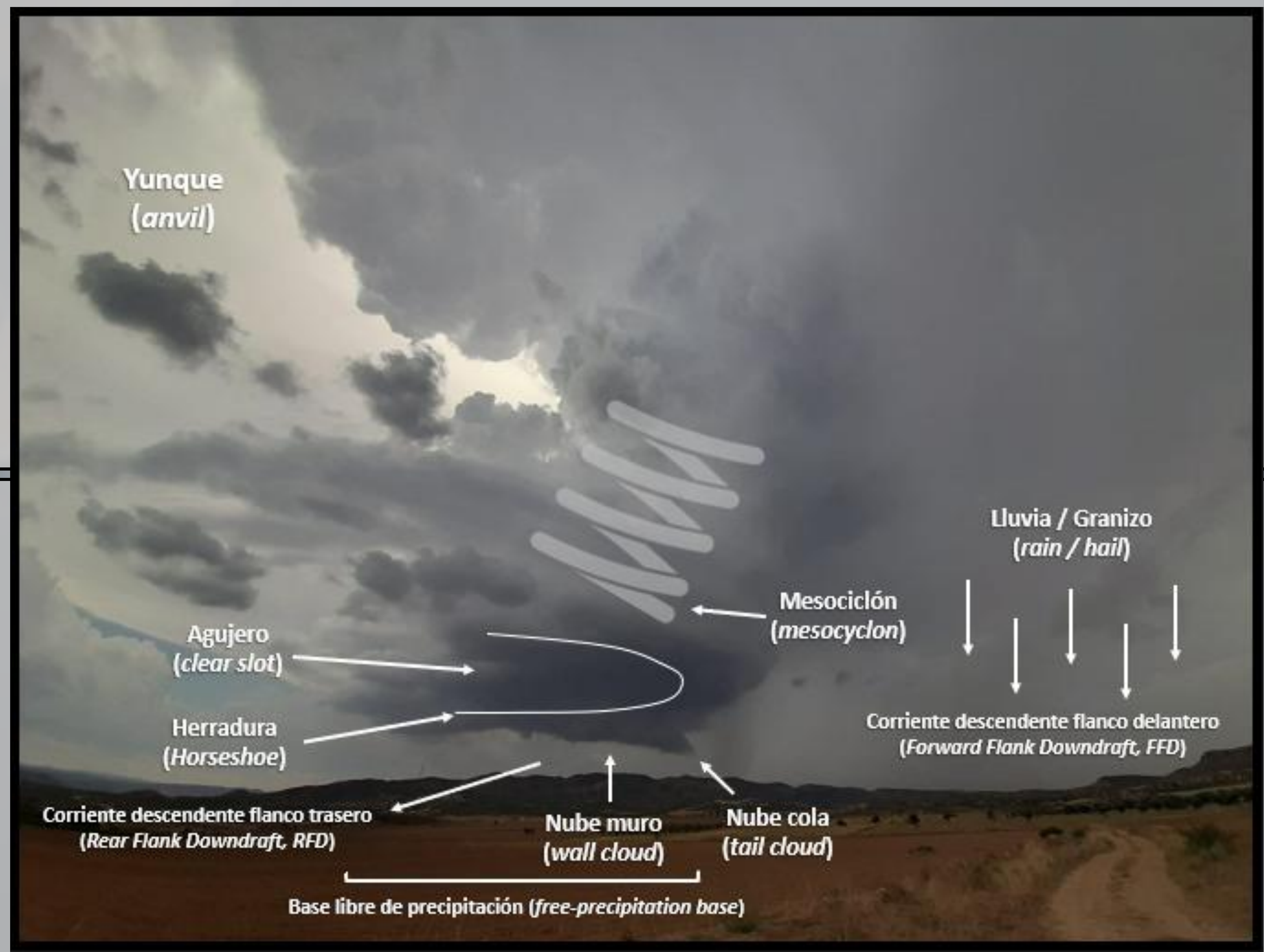


Figure 6: Supercell in Calanda (Teruel, Spain). August 14, 2020. Image: Juanma Bernad.

- ✓ The three parcels of CAPE present a wide range of values with different violin shapes.
- ✓ American supercells have a median CAPE of 1100 J/Kg (Rasmussen and Blanchard, 1998) and Iberian tornadoes around 1000 J/Kg (Rodriguez and Bech, 2020)
- ✓ Mixed-Layer CAPE have a median of 742 J/Kg and a frequency around of 500 J/Kg; The median of Most-Unstable CAPE is 1021 J/Kg and the frequency is 950/1000 J/Kg; and, Surface-Based CAPE has a median and more frequency around 950 J/Kg.
- ✓ The median and the frequency of the parcels of CIN are very similar, around -20 J/Kg.
- ✓ The range of values of the different parcels are not the same: SBCIN has a wide range of values, but MUCIN and MLCIN have a narrow range of values and more concentrated.

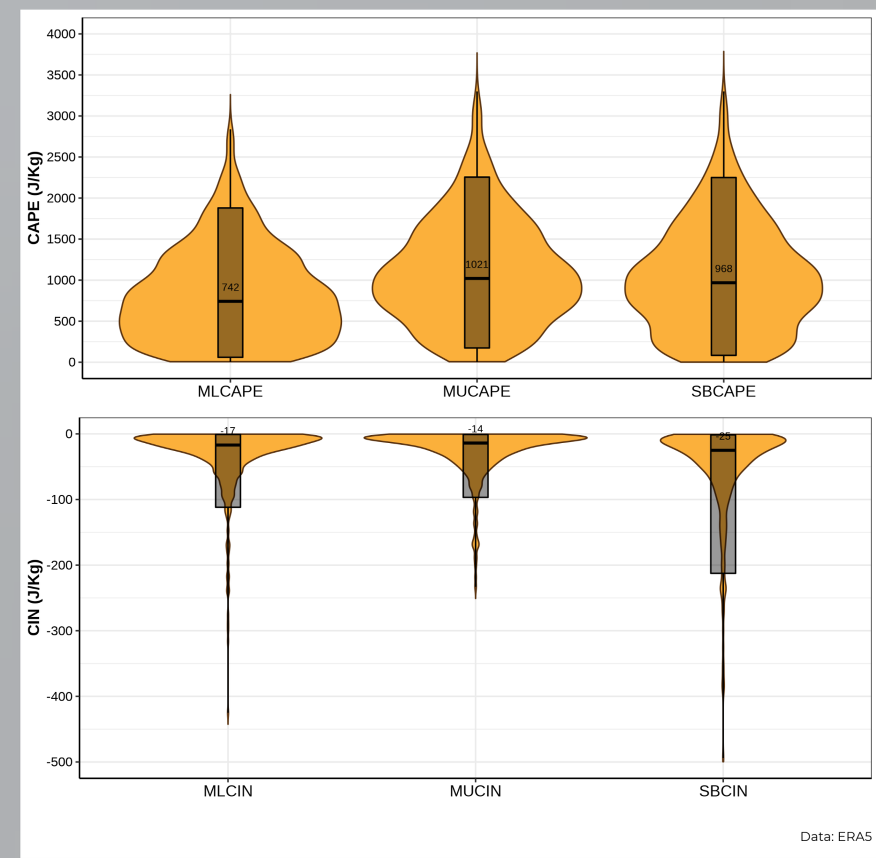
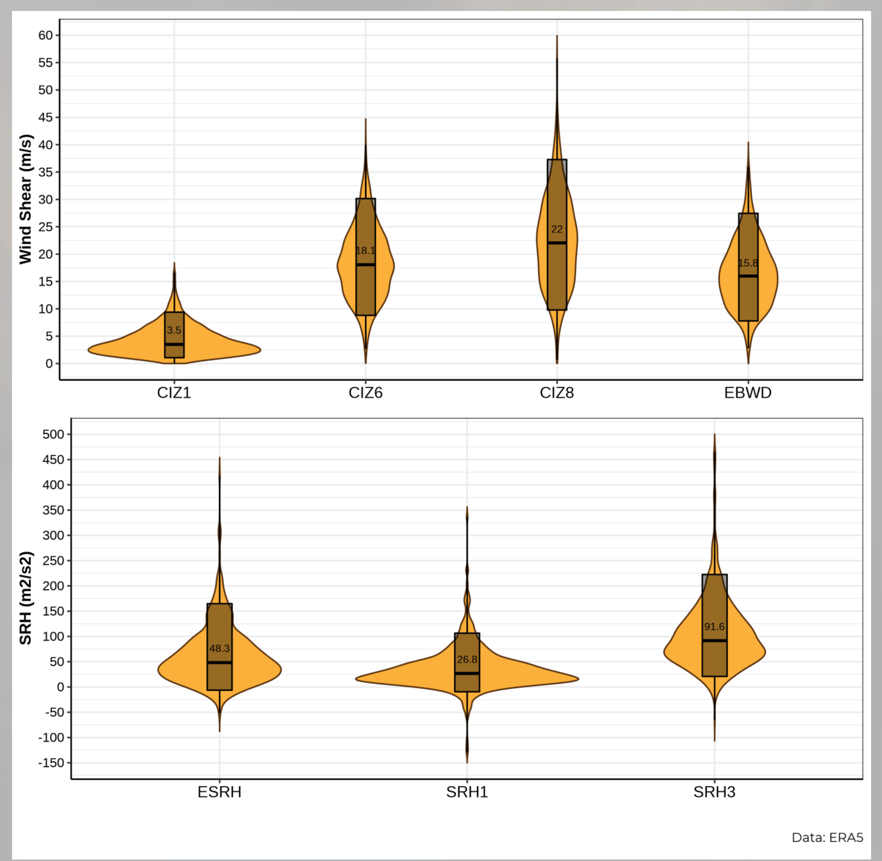


Figure 3: As Figure 1, but for SBCAPE, MLCAPE and MUCAPE (above) and SBCIN, MLCIN and MUCIN (bottom).

Figure 4: As Figure 1, but for WS01, WS06, WS08 and EBWD (above) and SRH01, SRH03 and ESRH (bottom).



- ✓ Kinematic parameters are the most important variables to explain supercell formation in Spain.
- ✓ American supercells have a median WS06 of 19 m/s and SRH03 of 125 m2/s2 (Rasmussen and Blanchard, 1998); and Iberian tornadoes around 18 m/s and 100 m2/s2, respectively (Rodriguez and Bech, 2020).
- ✓ The median and more frequent value of WS06 of Spanish supercells is around 18.1 m/s; and for SRH03 is 91.6 m2/s2, which are below American supercells and Iberian tornadoes.
- ✓ It is important to mention that supercells can form with lower WS06 and SRH03.
- ✓ Also, positive values of SRH denotate that he most Spanish supercells are cyclonic and only a few are anticyclonic.

- ✓ Composite parameters gives forecasters an important tool to forecast severe weather due to its ability to concentrate several key variables into one easy-to-understand index.
- ✓ The median value of Supercell Composite Parameter (SCP) of Spanish supercells is 1, while the American supercells have a median around 6. This great difference may be due to low values in CAPE and Kinematic parameters.
- ✓ This issue also happens in Significant Hail Parameter (SHIP) and Significant Tornado Parameter (STP): the median in Spain is 0.3 and 0.1, respectively, and in the USA these values revolve around 1.

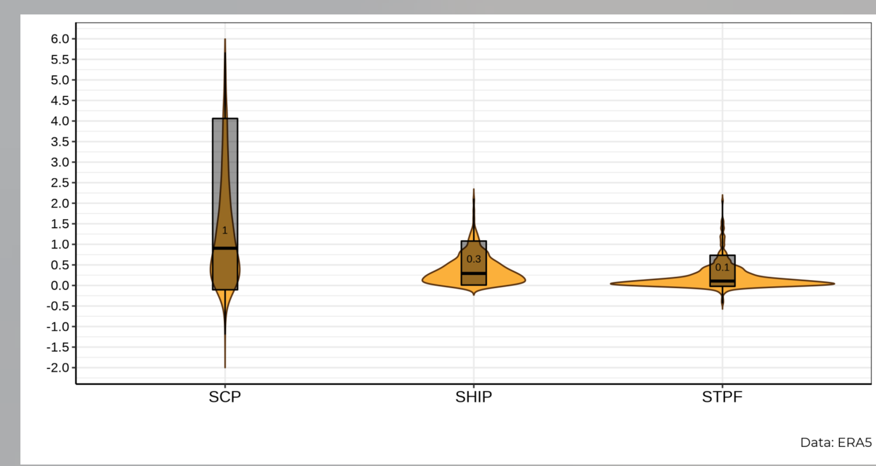


Figure 5: As Figure 1, but for Supercell Composite Parameter, Significant Hail Parameter and Significant Tornado Parameter.

CONCLUSIONS

1. Spanish supercells form, on average, in 1000 J/Kg CAPE, 18 m/s WS06 and 90 m2/s2 SRH03 environments.
2. The majority of Spanish supercells are developed in the Warm Season due to the values of T2M and DWPT.
3. The average values of thermodynamic and kinematic parameters of Supercell formation in Spain are somehow similar to the ones measured in the USA, however, the average values of the main composite parameters differ significantly.
4. This study will help forecasters to better predict severe weather in Spain.

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European Geosciences Union
Assembly 2021

Supercell Spatiotemporal distribution for 2011-2020 period