Predictors of large hail, severe convective wind gusts and tornadoes in Europe and the US: challenges towards global convective hazard models

European Severe Storms Laboratory

Climate Change and Extreme Events

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Introduction

We develop **Additive Logistic Regression models** for (very) large **hail**, **tornado** and **severe convective wind** gusts model using:

- Convective parameters from the ERA5 **reanalysis**.
- **Severe reports** from the European Severe Weather Database (ESWD) and the Storm Prediction Centre (SPC).
- **Lightning observations** from the Met Office Arrival Time Difference network (ATDnet) and the National Lightning Detection Network (NLDN).

Biggest challenge: **To develop a model using the same atmospheric predictors across different training regions** (e.g., Europe and the US)

Eventually this could allow to **apply convective hazards models globally.**

Methodology

The convective hazard models are developed taking convective initiation explicitly into account as done by Rädler et al. (2019).

$$P_{hazard} = P_{lightning} \cdot P_{hazard|lightning}$$

Model selection is conducted using the Deviance Explained (the higher the better) and the Bayesian Information Criterion (BIC, the lower the better) scores. 2D Histograms showing the relative frequency of convective hazards to thunderstorms occurrence are also evaluated.

Deviance Explained | **Bayesian Information Criterion** | **2D Histograms**

The predictive skill of selected predictors is checked across different training regions and sub-regions (see Tables). Predictors whose skill is high regardless of the training region are selected for model development.

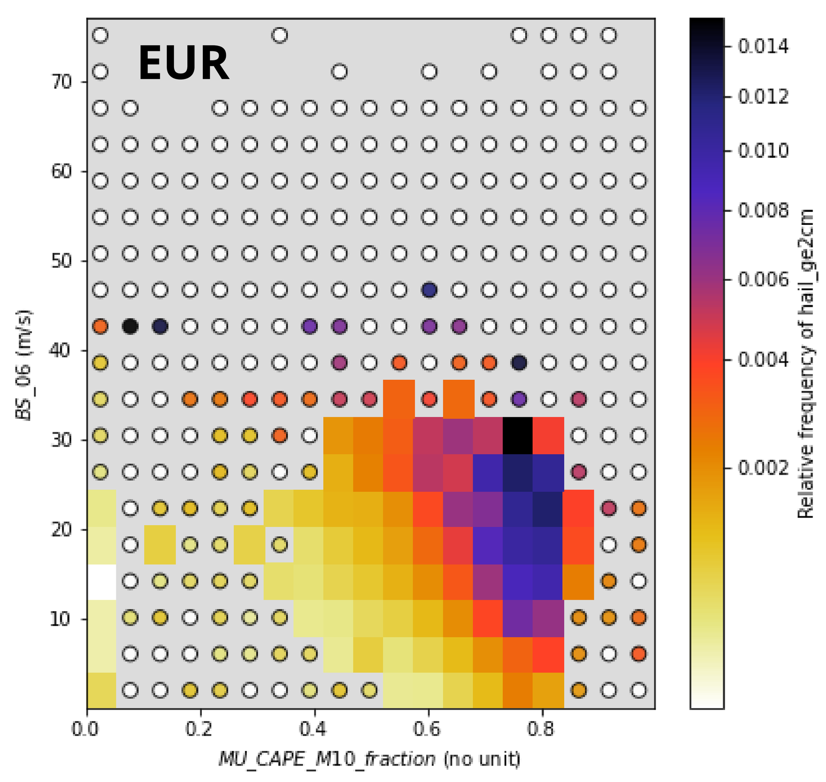
Large hail model development

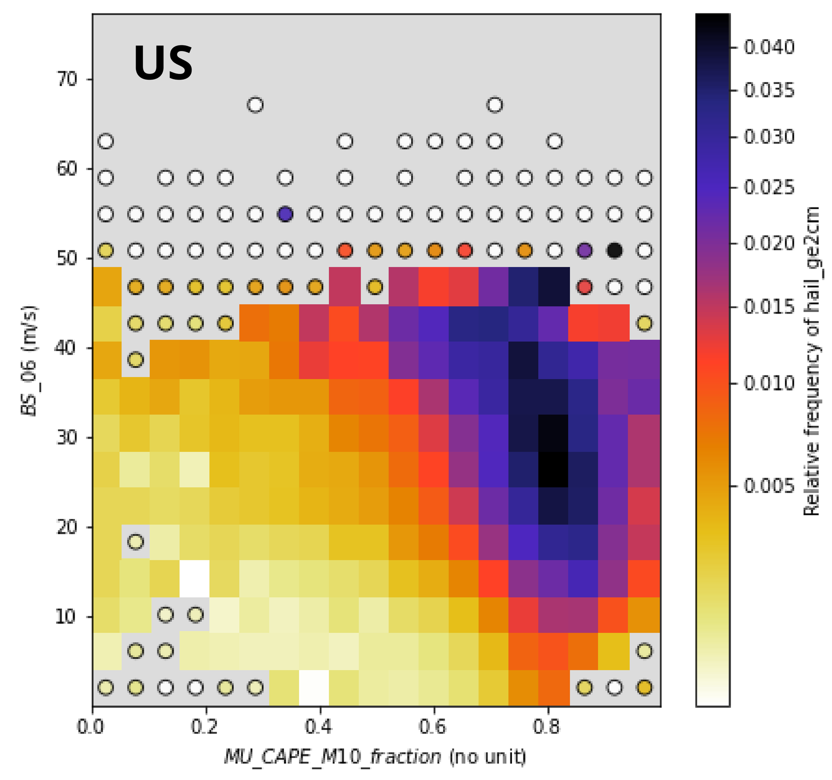
Sensitivity of instability predictors to geographical regions

	Central Europe	U.S.	U.S. Southeast	U.S Southern Plains
	Deviance explained (%)			
MU_CAPE	6.38	4.54	2.02	7.35
ML_CAPE	6.26	3.25	0.80	5.67
SB_CAPE	6.39	2.96	0.60	5.97
MU_CAPE_HGL	5.99	2.77	0.90	4.76
MU500_CAPE	6.26	5.94	3.45	7.69
MU_CAPE-10°	7.34	7.01	6.04	9.15
MU500_CAPE-10°	7.43	7.28	6.35	9.95
LR_3-6km	1.50	6.86	6.17	5.57
BS_0-6km	1.39	4.10	4.12	3.47
EFF_MU_BS	4.81	6.84	5.49	6.53

- CAPE variants are the best thermodynamic parameters in Europe
- Lapse Rates perform better in the US
- CAPE is a poor predictor in the US Southeast
- Thermodynamic parameters better than shear ones for hail > 2 cm

The only thermodynamic predictor with a high skill in all regions (Europe, the US and subregions) **is the CAPE released above -10°C.**

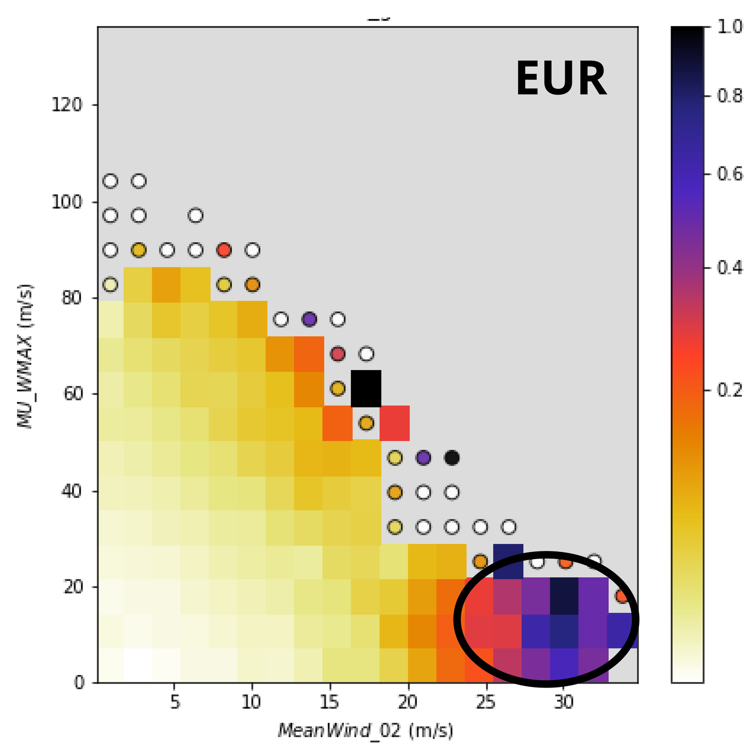


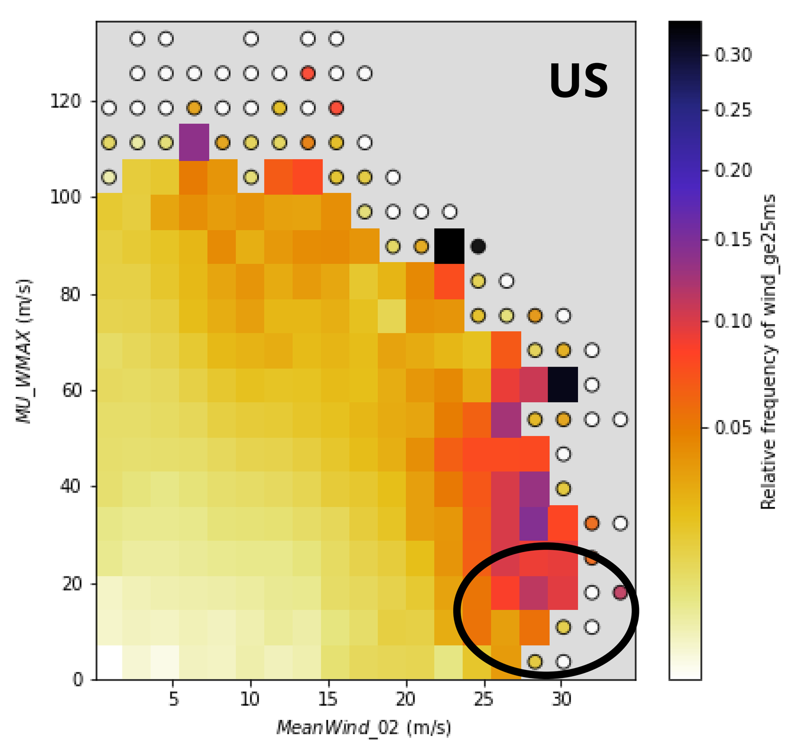


Models based on the CAPE released above -10°C can reconstruct well hail climatologies across both Europe and the US.

Wind model development

Environmental conditions associated with severe convective wind gusts **significantly differ between EUR and US.** This complicates the development of a common model for the two regions.





The **largest relative frequency** of severe convective wind gusts is found **in High Shear – Low CAPE (HSLC) regimes.**

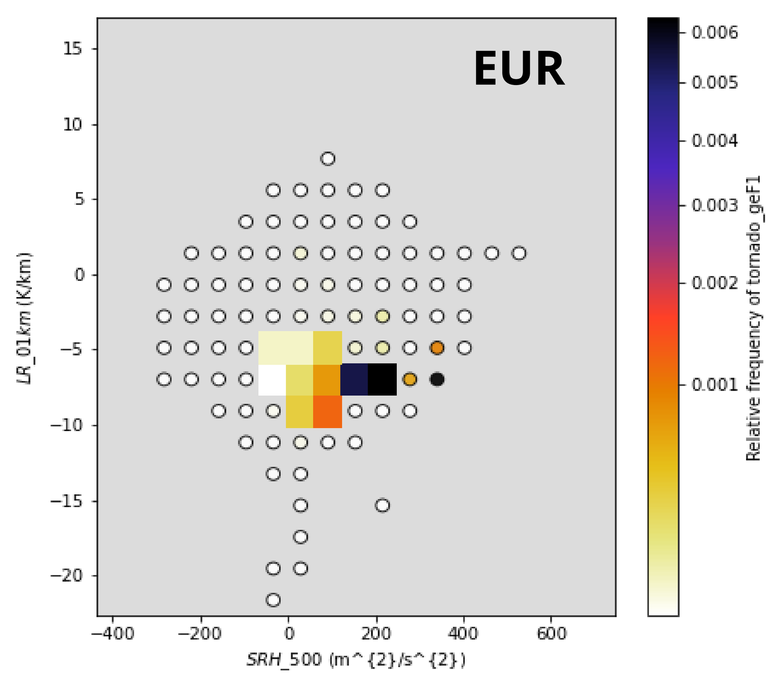
HSLC environments are much less likely to produce severe convective wind given the same parameter space.

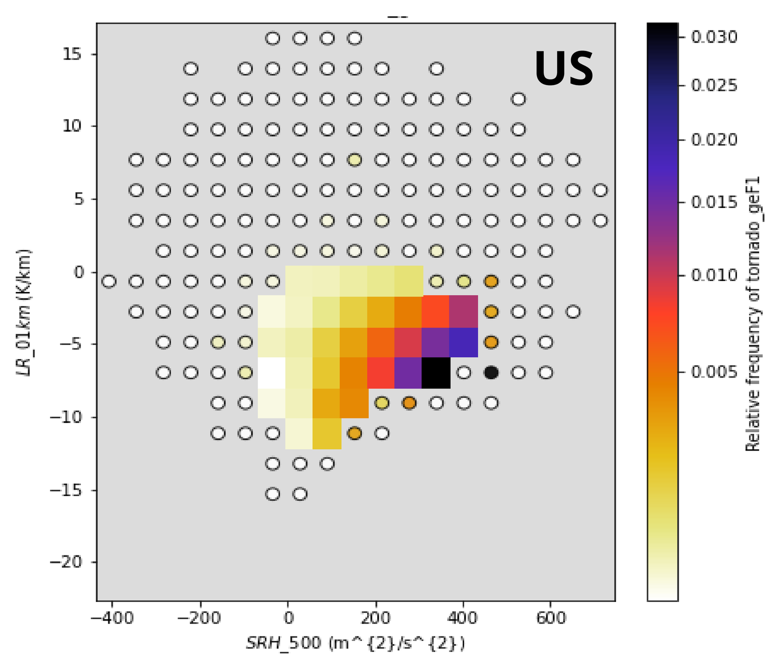
Tornado model development

Predictors performance

	Europe	U.S.
	Deviance explained (%)	
SRH_100m	6.14	15.50
SRH_250m	5.72	14.90
SRH_500m	5.50	12.80
DLS	3.97	8.66
0-3_SBCAPE	1.06	1.71
SB_WMAX	1.02	1.31
LR_500m	1.28	3.06
LR_0-1km	1.30	2.01
LR_0-2km	1.05	1.24
ML_LCL	0.58	1.20

2D Histogram SRH_100m and LR_01_km

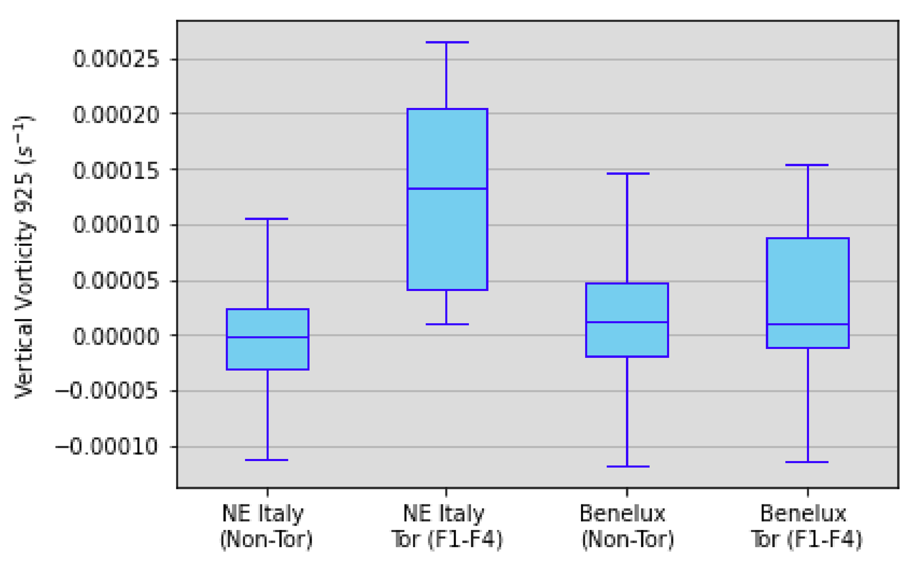




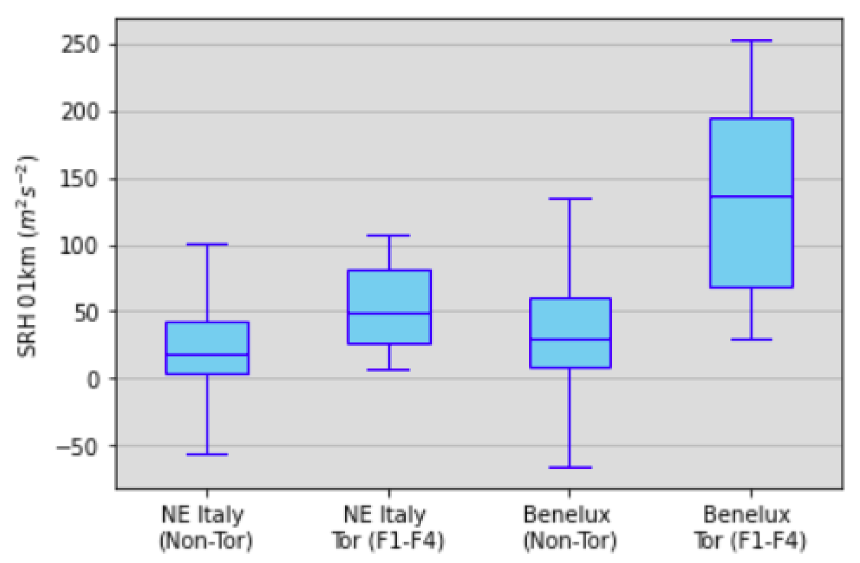
- **SRH_100m** is the best single predictor for tornadoes across both EUR and US
- **Instability** related **parameters** are much **less skillful**
- The combination of **SRH_100m and LR_01km** gives the highest predictive skill as a 2-dimensional model

Different regions different predictors

Tornadoes are difficult to model, one of the causes is that the conditions in which they generally occur differ regionally. An example of this represented by the **Po Valley** in Northern Italy where tornadoes occur in relatively **high LCLs and low SRH values**



Near surface vertical vorticity best predictor **in N Italy**



SRH_01km works better elsewhere e.g., Benelux countries

Tornado climatology 2008-2020

Based on test model

LR_01km

Vorticity 925 hPa