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Identifying Hotspots of Convective Events in the European Alps by Analyzing Synoptic Circulation Types and Report Data of the last 33 Years

Helge Jentsch, Katharina Schröer

Climate Geography Lab (CliG), Faculty of Environment and Natural Resources, University of Freiburg

Background

- Convective storms **cause many hazardous hydrometeorological events**, impacting many people throughout Europe, especially near the Alps
- Due to the **increased saturation vapor pressure** convective processes intensify through **global warming**, given sufficient moisture availability
- **Precipitation intensification** can already be **identified in observations**, while studies on other events (e.g. hail) are not yet conclusive
- **Severe weather reports** from the European Severe Weather Database (ESWD, Fig. 1) show **distinct regions of intense convective activity** in the vicinity of the Alps

Aims

- Identifying **cross-scale processes** of convective events in the **European Alpine Region**
- **Hotspot identification** in the Greater Alpine Region
- Understanding **Hotspot environments** by characterization of large scale environments

Approach

Classification of flow regimes and spatio-temporal analysis of severe weather events **systematically from synoptic to regional scale**

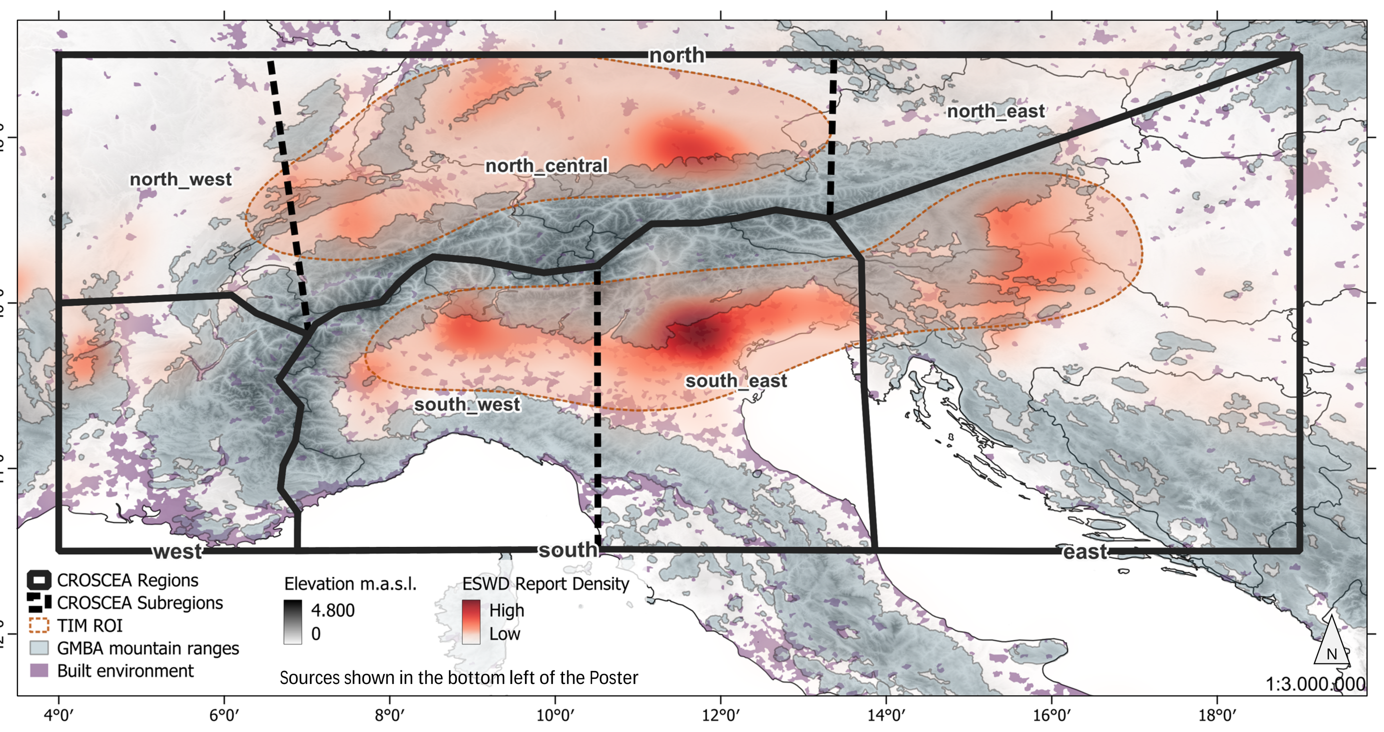

Fig. 1: Report density of ESWD Data (Dotzek et al. 2009) around the European Alps with regions of interest (ROI). Adapted from Fischer et al. (2025).

Classifying Circulation Types

(1) Using **Cost733class** software (PCACA) (Philipp et al. 2014)

- 18 circulation types (CT) (Fig. 2) focusing on convective environments
- Based on **ERA5** mean sea level pressure (MSLP), 500 hPa geopotential (z_{500}), wind speed at 700 hPa (ws_{700}), CAPE (all at 12UTC) (Hersbach et al. 2020; Schröer & Tye 2019)
- Issues: inefficient, hard to modify

(2) Own **Python implementation** for more flexibility

- Principal Component Analysis with Hierarchical Clustering and K-Means Clustering
- Fast modification of domain and spatial resolution
- Both simple large-scale flow (general circulation types) and clustering of regional patterns including more variables

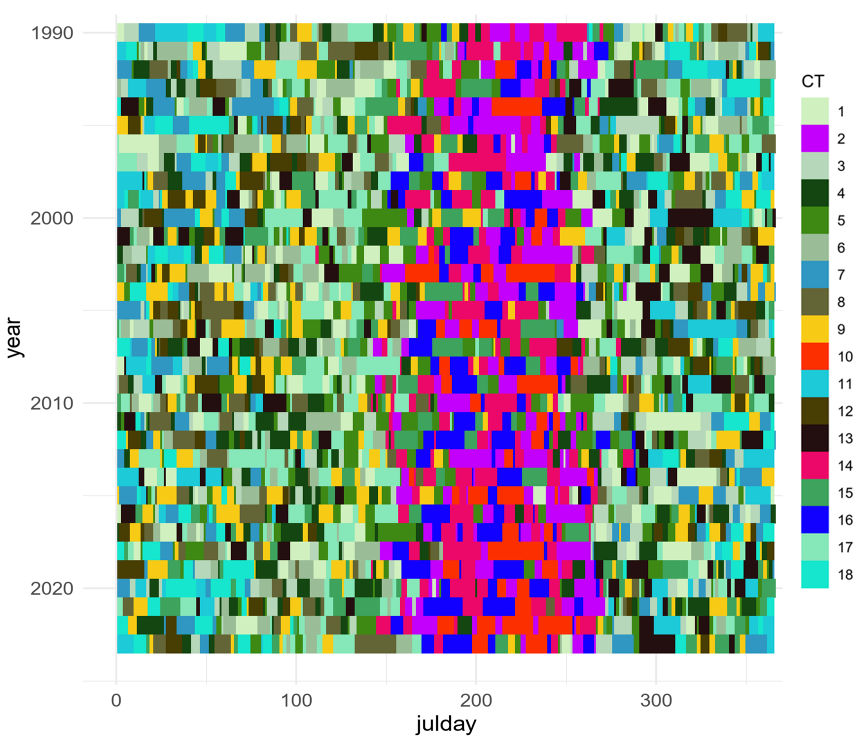

Fig. 2: Example: Daily distribution of occurrences of Circulation Types (CTs)

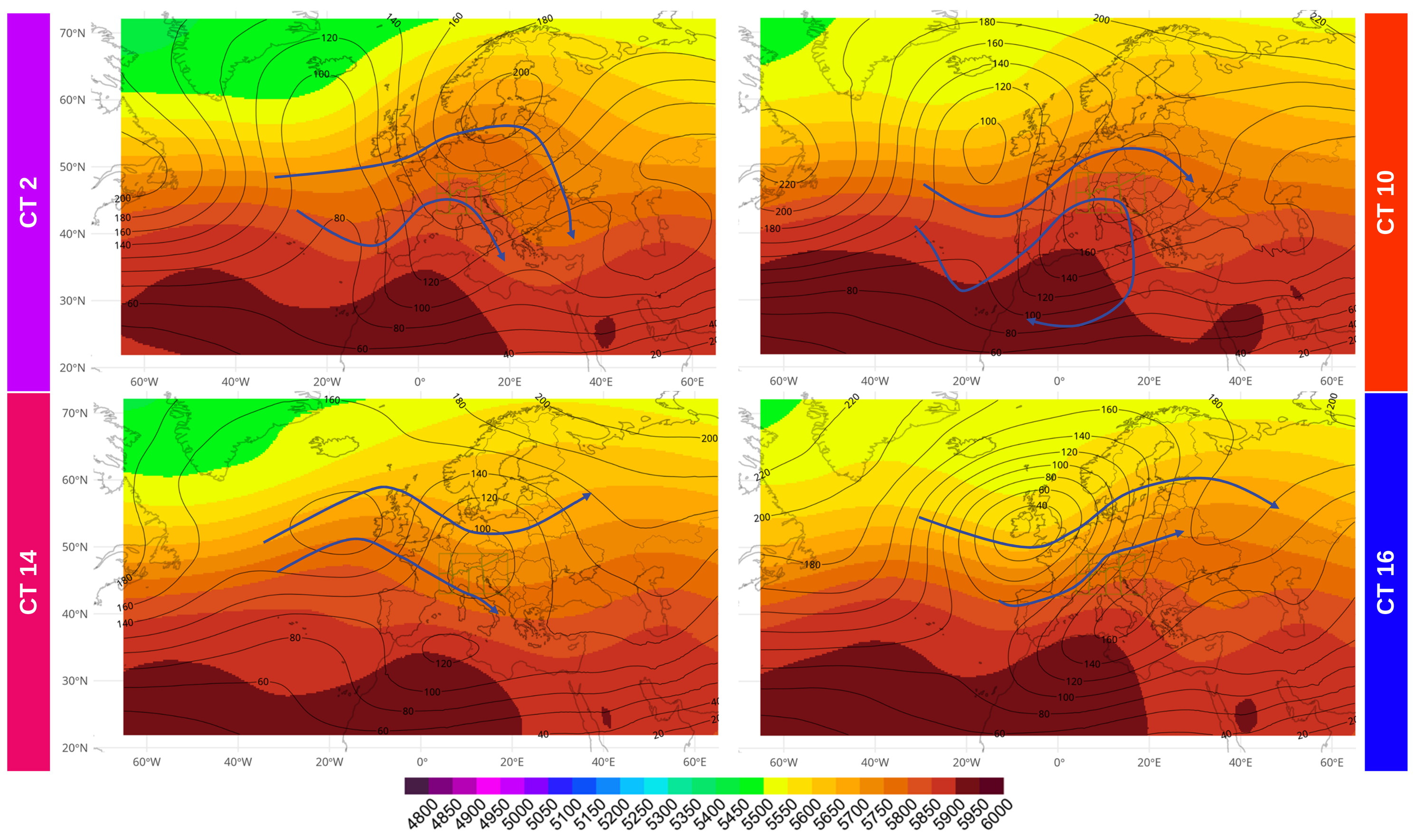

Fig. 3: Mean geopotential height in meters with anomalies as contours and mean wind flow as arrows for the four summertime convective circulation types 2, 10, 14, and 16 from the initial Cost733class classification trials.

Preliminary Results

Large Scale

Figures 2 & 3

- CTs 2, 10, 14, and 16 show **highest number** of **reported** convective **severe weather events**
  - CT 2 – clustered northern activity
  - CT 14 – activity in the South and East
  - CT 10 – strong activity North and South
  - CT 16 – highest overall activity
- **Relative shares of ESWD reports** during convective CTs **stayed constant** throughout **the decades**
- Convective CTs show **more persistent** and **longer duration** than other CTs (Fig. 2)
- Mean sea level pressure indicate **weak gradients** over Central Europe during **high activity CTs**

Regional Scale

Figure 4

- Daily reports that include **at least 15 entries**, with **min. 80% from a single region** during the **convective season** → **Dominant day** with region
- Dominant report types per region:

Wind, Hail

Wind, Precip (W) — (E) Precip, Hail

Hail, Precip

Region	Dominant Days	Dominant CT	Reports GAR	Reports Region
North	77	16	2862	2629
East	38	16	1034	928
South	29	14	929	839
West	12	1	249	219

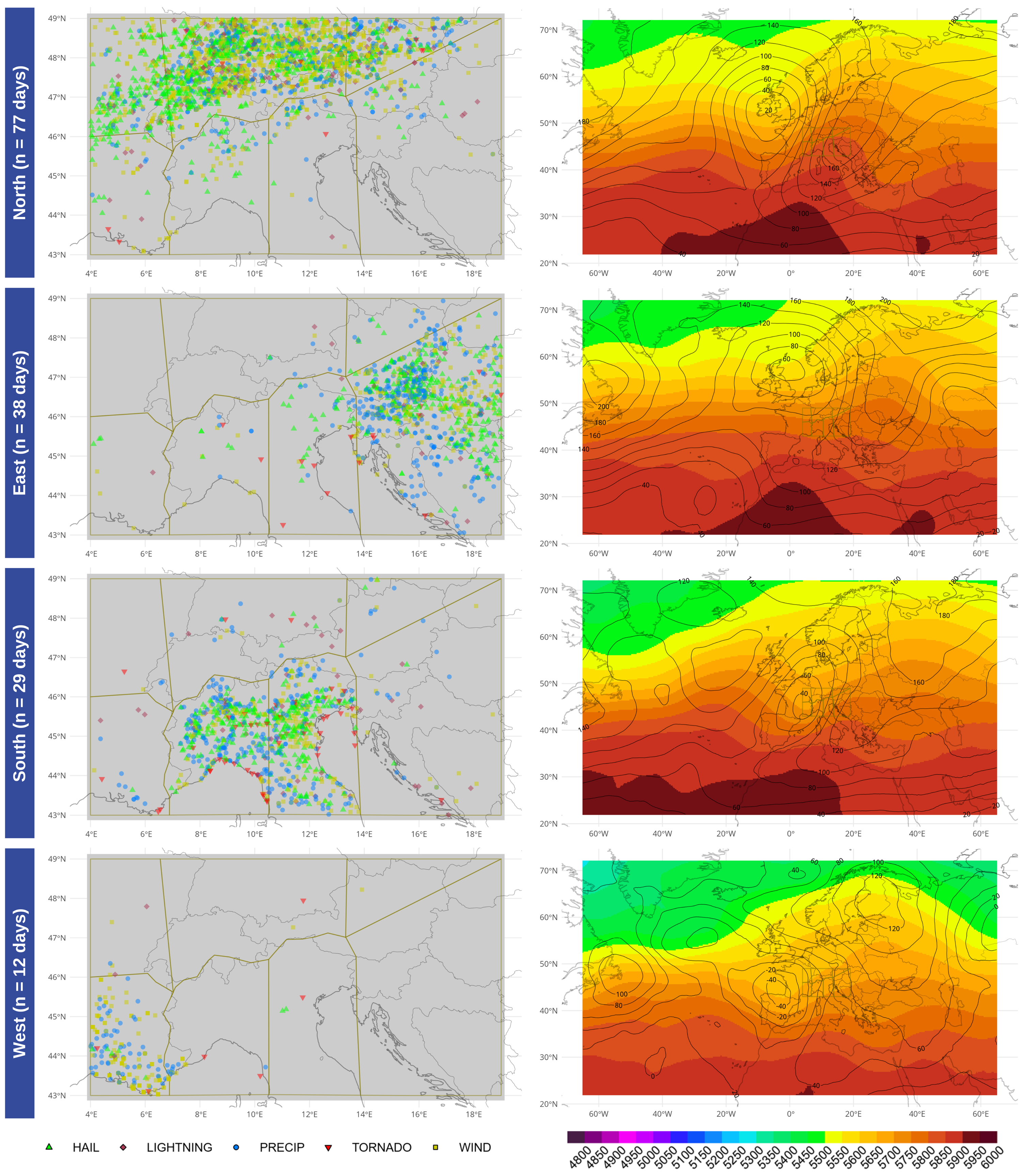

Fig. 4: The left-hand column shows the cumulative reports from days where the respective regions dominate the reporting behavior (rows). The right-hand panels show the corresponding mean z_{500} (colors) and anomalies (contours) in meters for these days.

Work in Progress

- Extending the clustering methodology to fast and flexible **Python implementation**
- Developing **robust classifications** of both **general circulation types** (MSLP, z_{500}, wind, European/North Atlantic domain) and **regional patterns** in the Greater Alpine Region
- From reports to events: **DBSCAN clustering** of reports
- Indication of **significance** of e.g., anomalies
- **Interpreting** atmospheric patterns and anomalies and event report densities

Future Plans

- Identifying **drivers for hotspot activation** in the CROSCEA regions on the large and regional scale
- So far, only crowdsourced reports are used as indicators for severe weather occurrence
- **Collecting and assembling observational data** from Alpine countries: have any? Talk to us 👋

I would like to thank Andreas Prein and Pieter Groenemeijer for their valuable insights and feedback during my PhD project.

Figure data sources:
Country boundaries (Fig. 1,3,4) & Build environment (Fig. 1): NatualEarthData; Mountain Ranges (Fig. 1): Snethlage et al. (2022a,b); Report data (Fig. 1,4): Dotzek et al. (2009)

- Dotzek, N., P. Groenemeijer, B. Feuerstein, and A. M. Holzer. 2009. "Overview of ESSL's Severe Convective Storms Research Using the European Severe Weather Database ESWD." Atmospheric Research, 4th European Conference on Severe Storms, 93 (1): 575–86. https://doi.org/10.1016/j.atmosres.2008.10.020.
- Fischer J., P. Groenemeijer, A. M. Holzer, M. Feldmann, K. Schröer, F. Battaglioli, L. Schielicke, T. Púčik, Ch. Gatzen, B. Antonescu, and TIM Partners. 2025. "Invited Perspectives: Thunderstorm Intensification from Mountains to Plains." Natural Hazards and Earth System Sciences 25 (8): 2629–56. https://doi.org/10.5194/nhess-25-2629-2025.
- Hersbach H. , B. Bell, P. Berrisford, Sh. Hirahara, A. Horányi, J. Muñoz-Sabater, J. Nicolas, et al. 2020. "The ERA5 Global Reanalysis." Quarterly Journal of the Royal Meteorological Society 146 (730): 1999–2049. https://doi.org/10.1002/qj.3803.
- Philipp A., Ch. Beck, P. Esteban, et al. 2014. COST733CLASS v1.2 User Guide.
- Schröer K., and M.R. Tye. 2019. "Quantifying Damage Contributions from Convective and Stratiform Weather Types: How Well Do Precipitation and Discharge Data Indicate the Risk?" Journal of Flood Risk Management 12 (4): e12491. https://doi.org/10.1111/jfr3.12491.
- Snethlage, M.A., Geschke, J., Spehn, E.M., Ranipeta, A., Yoccoz, N.G., Körner, Ch., Jetz, W., Fischer, M. & Urbach, D. A hierarchical inventory of the world's mountains for global comparative mountain science. Nature Scientific Data. https://doi.org/10.1038/s41597-022-01256-y (2022a).
- Snethlage, M.A., Geschke, J., Spehn, E.M., Ranipeta, A., Yoccoz, N.G., Körner, Ch., Jetz, W., Fischer, M. & Urbach, D. GMBA Mountain Inventory v2. GMBA-EarthEnv. https://doi.org/10.48601/earthenv-t9k2-1407 (2022b).

Helge Jentsch
helge.jentsch@geographie.uni-freiburg.de

University Profile — LinkedIn — ResearchGate

Climate Geography Lab Freiburg

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