Conditions during the formation of warm-season derechos in Central Europe during last 25 years

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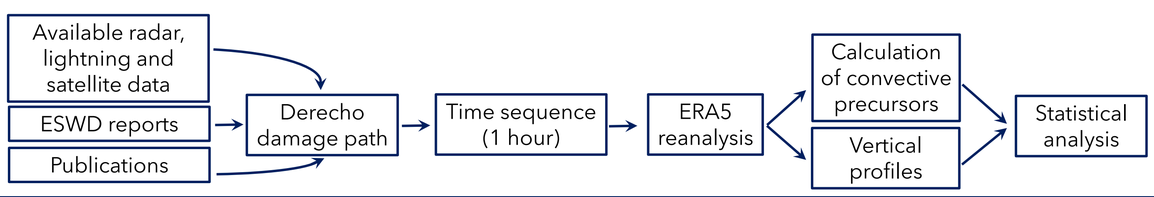
Introduction

- **Derechos are widespread, severe windstorms that originate from mid-latitude mesoscale convective systems (MCSs) driven by cold pools and other internal forcing mechanisms.**
- For an event to be classified as a derecho, it must affect an area along a path longer than 400 km, producing widespread severe winds with gusts exceeding 26 m/s, with at least 3 reports of measured wind gusts over 33 m/s, or causing equivalent damage according to the Fujita scale.
- Derecho windstorms can be categorized according to their intensity into **low-end, moderate, and high-end derechos:**
  - **Low-end** – No reports of wind gusts over 33 m/s or equivalent damage according to the Fujita Scale
  - **Moderate** – At least 3 reports of wind gusts over 33 m/s or equivalent damage
  - **High-end** – At least 3 reports of wind gusts over 38 m/s or equivalent damage
- In relation to the synoptic forcing, cases can be divided into **weak forcing (progressive) derechos**, where there is no significant influence from synoptic-scale features or cold fronts; **hybrid derechos**, with some influence of synoptic forcing; and **strong forcing (serial) derechos**, where synoptic-scale features and cold fronts have a significant impact. In our study, we focus only **on warm-season weak-forcing and hybrid events.**

Methodology

- The main source for reconstructing derecho damage paths was the ESWD database, combined with available radar data, data from the Blitzortung network and publications. Some derecho paths (particularly on the Balkan Peninsula) were further refined using satellite data from the MSG satellite.
- Convective precursors were calculated from the ERA5 reanalysis using the ThundeR package (https://rawinsonde.com) for the two hours preceding a derecho's arrival at a given location along its damage path.
- Vertical profiles, such as equivalent potential temperature and air humidity, were also derived from the ERA5 reanalysis.
- Subsequently, the variables and profiles were analyzed with respect to the different stages of derecho development: initiation (the first 3 hours), mature, and decay (the last 2 hours).



Key results

- We analyzed over 50 derechos from 1998 to 2023 in Central Europe.
- Derechos in Central Europe often form on the northwestern base of the Alps, near the German–Swiss border or over Switzerland. The main regions where derechos tend to dissipate are central Czechia, central Slovakia, and parts of central Germany and Poland, as well as the Baltic Sea.

Vertical profiles of temperature, moisture and wind

- Derechos form and develop (beginning and mature phase) under similar conditions in terms of vertical moisture profiles; however, when the system decays and ceases to produce strong winds, there is less RH throughout the entire profile.
- Derechos in Central Europe develop at much lower θe than derechos in the USA (related to lower instability in Central Europe), and the θe profiles in Central Europe are very similar during the beginning and decay phases.
- Derechos in Central Europe develop under lower RH at low levels, often showing an inverted-V pattern on SKEW-T, and with higher RH at mid-levels.
- Median hodographs are not significantly curved, and 0–3 km SRH remains largely unchanged throughout a derecho's lifecycle.

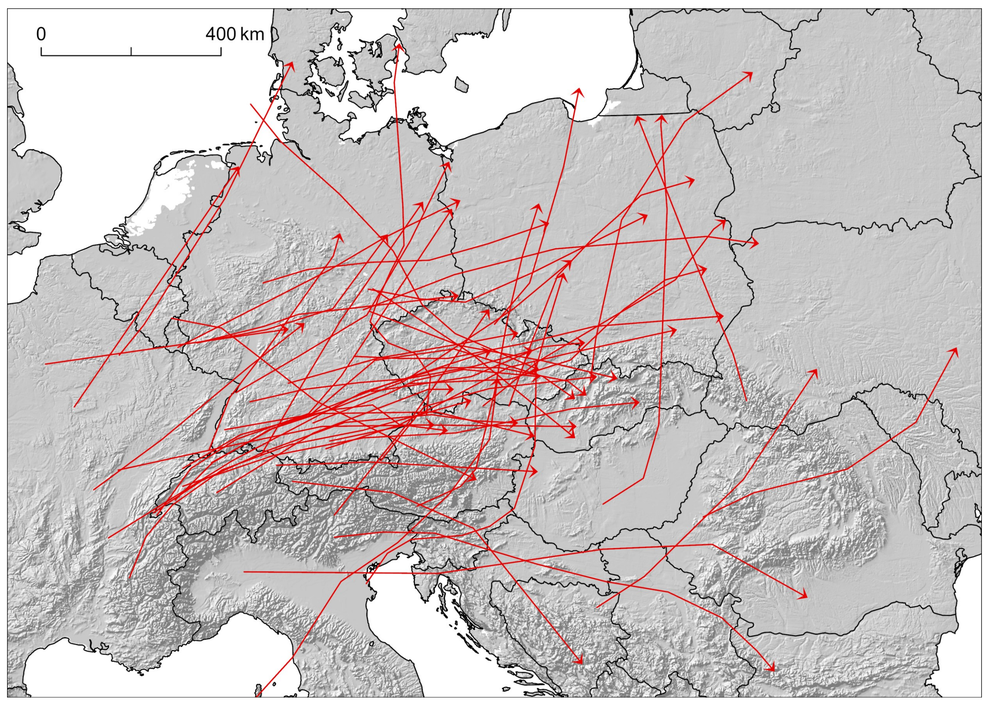
Conditions during the lifecycle of derechos

- Derechos most often form under higher DLS (Deep Layer Shear) values (median 22.9 m/s) and gradually propagate into environments with lower DLS, dissipating at a median DLS of 15.8 m/s (during the last hour when wind gusts or damage were reported in the area). DLS during the last two hours of the derecho life cycle has a median of 16.5 m/s.
- The decay phase of derechos is most often caused by a weaker lapse rate between 0 and 1 km, more pronounced CIN, and lower CAPE – which, in the case of MU CAPE, drops to 950 J/kg during the final two hours of the derecho life cycle and to only 811 J/kg in the last hour.
- Compared to some publications from the USA (Evans and Doswell 2001; Doswell and Evans 2003), derechos develop under lower CAPE and DCAPE values but with stronger vertical wind shear in Europe.
- Median hodographs are straight and SRH 0-3 km remains very similar throughout the entire lifecycle of derechos.

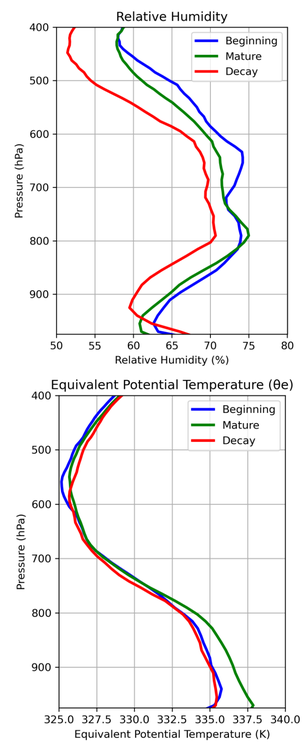
Extreme cases

- Derechos that move from south to north (10–11 August 2017, 20 July 2011) develop under higher precipitable water values than other derechos.
- The strongest SRH 3 km RM (over 500 m^2/s^2) occurred during the 11 August 2017 and 18 August 2022 derechos.
- The highest CAPE was observed during the development of the 18 August 2022 derecho (MU CAPE around 6000 J/kg, ML CAPE around 4000 J/kg) in combination with strong DLS (between 30 and 35 m/s). At the same time, this derecho moved nearly 400 km across the Alps into the Czech Republic under CAPE of only a few hundred J/kg and DLS around 15 m/s, being driven during its decay mainly by low humidity at low levels and a pronounced low-level lapse rate.
- The lowest precipitable water occurred during the 11 July 2023 derecho (mean 27 mm, lowest values < 20 mm), where DCAPE was high (around 1200 J/kg).

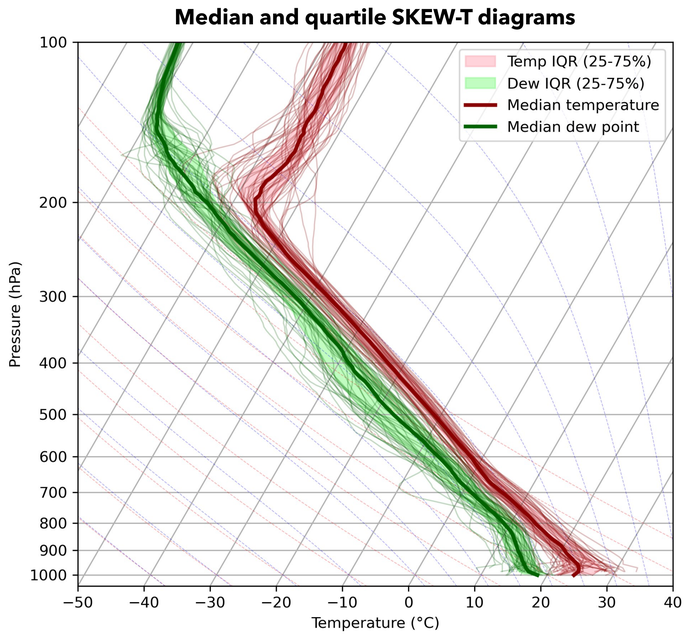
Centerlines of analyzed weak forcing and hybrid derechos from 1998 to 2023



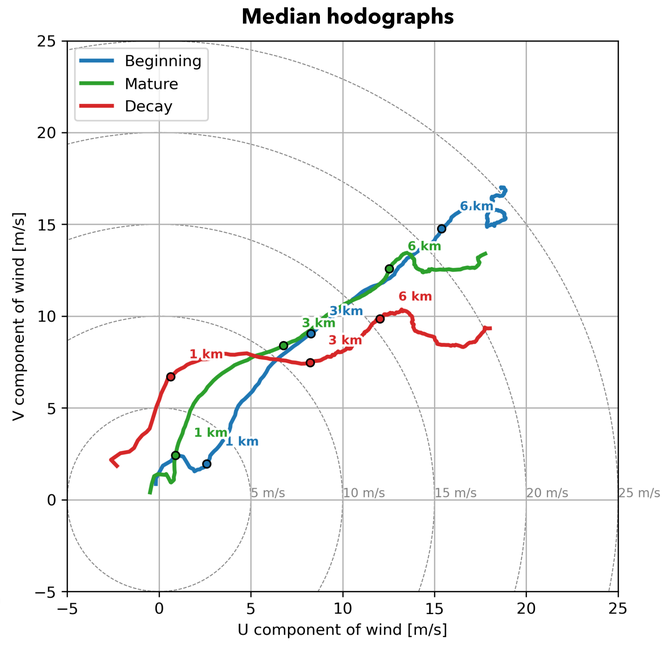
Median profiles of RH & θe



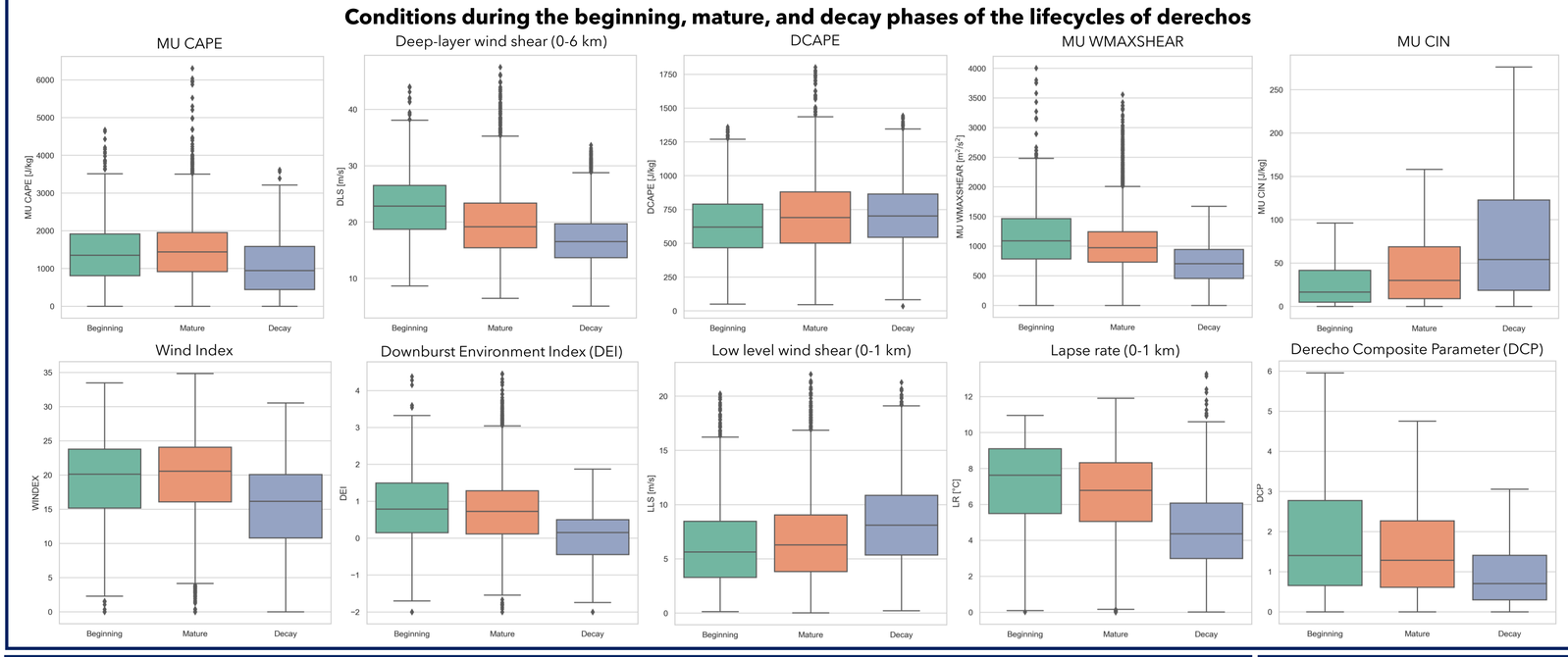
Median and quartile SKEW-T diagrams



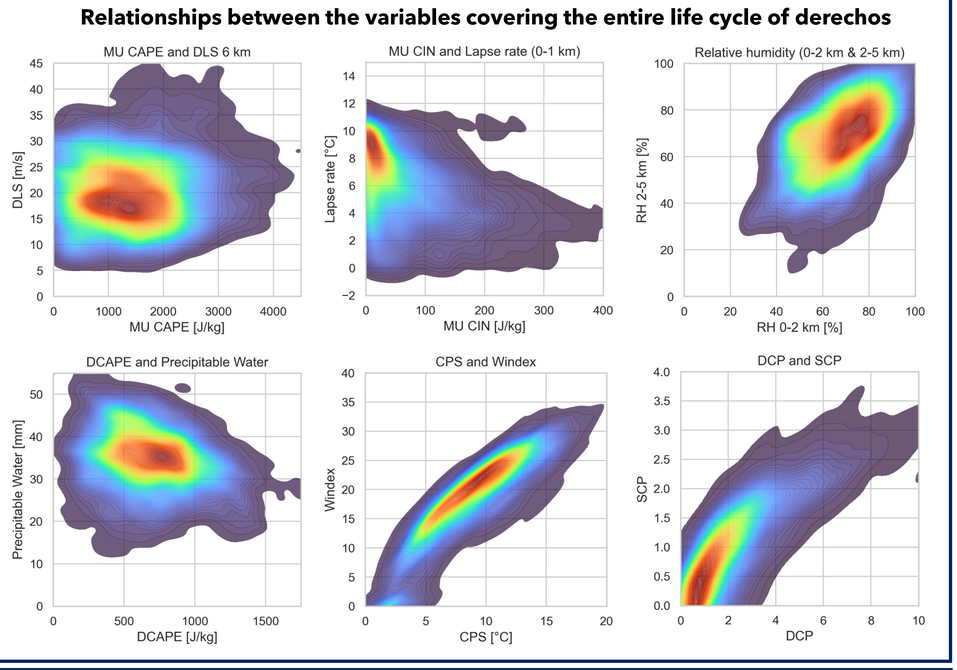
Median hodographs



Conditions during the beginning, mature, and decay phases of the lifecycles of derechos



Relationships between the variables covering the entire life cycle of derechos



Future work

- Include the area during the decay phase in which the system did not produce strong winds, and compute the precursors for this location using the ERA5 reanalysis.
- Process anomalies of key variables (such as CAPE, DLS 0-6 km and WMAXSHEAR) over Central Europe based on the ERA5 reanalysis.
- Apply the same methodology to selected variables from the Perun-Aladin reanalysis at a high resolution of 2.3 km and use this dataset to analyze extreme environments in detail, particularly high-end derechos.
- Create a dataset of downbursts and downburst clusters (events smaller than a derecho but larger than a single downburst or two downbursts) for the period 1998–2024.
- Include the environmental conditions that lead to downbursts and downburst clusters over Central Europe, and compare these conditions.
- Expand the derecho dataset by adding new events from 2024 and from the 1990s.

Literature & references

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