Temporal variability of severe convective storms connected with hail events across Europe and their relevant drivers

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Overview

Due to a lack of long-term, reliable, and consistent information about the occurrence of severe convective storms (SCS) in Europe – especially those connected with hail events – we have developed methodologies that enable us to indirectly estimate thunderstorm and hail probability from numerical weather prediction or climate models. Using these two approaches, we investigated the temporal and spatial variability of convective precipitation and hail potential past decades and identified large-scale atmospheric processes (e.g., teleconnection patterns, SST, blocking) that determine the spatio-temporal variability of SCS.

Methodology

How can thunderstorm and hail probability estimated?

Proxy by Logistic hail model

Fig. 1: Modelling of the annual (summer) Potential hail index (PHI; coastDat2, 1953–2010; Mohr et al., 2012).

Fig. 2: (a) Mean annual (frequency index) of convection-favoring weather patterns (WMAA conditions; coastDat2, 1958–2014; SM; Piper, 2017; Piper et al., in prep.).

Variability

How is the temporal and spatial variability of convective activity and hail potential over past decades?

Proxy by Effective weather types

Fig. 3: Time series of the annual PHI (10-year rolling standard deviation; shaded) including 11-year moving average (dashed) for different locations (e.g., granonomic areas orisode (Open), Dijon (France), Milan (Italy); Mohr et al., 2013).

Fig. 4: Correlation coefficients (Dijon, Milan; and all other grid points; Mohr et al., 2012).

Relevant drivers

What are the large-scale atmospheric processes influencing the temporal and spatial variability?

Teleconnections

Fig. 5: Time series of convection-favoring weather patterns for different areas and annually averaged EA index (left) and sea surface temperature (SST) over the Bay of Biscay (right; Piper, 2017; Piper et al., in prep.).

Fig. 6: Regional trends of convection-favoring weather patterns for different areas and annually averaged EA index (dashed) for different locations (e.g., granonomic area orisode (Open), Dijon (France), Milan (Italy); Mohr et al., 2013).

Fig. 7: Relationships between the North Atlantic Oscillation (NAO) index and thunderstorm days, (based on lightning detections: EUCLID between 2002–2014). Presented is the difference deviation of the monthly number of thunderstorm days (anomaly) calculated with respect to months with an North Atlantic Oscillation (NAO) index greater than +1 (NAO+) and less than –1 (NAO–) and less results from a Bayesian significance test (right; Piper and Kunz, 2017).

Fig. 8: Same as Fig. 7, but for the East Atlantic (EA) pattern (Piper, 2017; Piper et al., in prep).

Fig. 9: Time series of convection-favoring weather patterns for different areas and annually averaged EA index (left) and sea surface temperature (SST) over the Bay of Biscay (right; Piper, 2017; Piper et al., in prep.).

Fig. 10: Relevant areas, where the occurrence of blocking influence the thunderstorm days (blue: reducing; red: increasing) in central parts of western and central Europe (see Fig. 12; Mohr et al., in prep.).

Fig. 11: Areas with statistically significant changes in the odds of thunderstorm days (2002–2014). Mixed influences of blocking activity in the study area. Decrease in odds of thunderstorm days with blocking activity in the study area. Decrease in odds in the study area. Decrease in odds in the study area. Decrease in odds in the study area.

Fig. 12: Areas with statistically significant changes in the odds of thunderstorm days (2002–2014). Mixed influences of blocking activity in the study area. Decrease in odds of thunderstorm days with blocking activity in the study area. Decrease in odds in the study area. Decrease in odds in the study area. Decrease in odds in the study area.

Conclusions

Little or no trend in PHI and convection-favoring weather types for most of the grid points (1951–2010/2014), but high annual variability of the conditions that favor severe convective events including hail.

Regarding weather pattern: Most regions feature positive trends for thermodynamic and negative trends for dynamic quantities: Positive trends for thermodynamic parameters, negative trends for lifting (not shown).

Larger-scale mechanism like teleconnections (e.g., NAO, EA) or SST substantially impact local-scale convective activity in Europe: e.g., increased convective activity during NAO+ and EA–.

Several simultaneous peaks in EA/SST time series and days with convection-favoring conditions.

Areas with blocking activity over the eastern North Atlantic (reduction) and Scandinavia influence (increasing) thunderstorm activity in western/central Europe. Reasons are resulting condition for the upper flow, moisture transport and stability conditions.