A Probabilistic Model for Severe Hail Risk in Europe

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Goal: Stochastic Hail Catalog

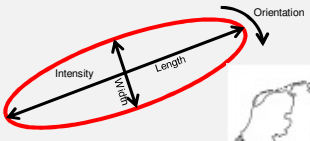
Stochastic catalog

- Set of plausible severe thunderstorm events
- Event = collection of one or more days of thunderstorm footprints
- Footprint modeled with an ellipse

Daily simulation

- Events are simulated at the daily level, based on historical seed dates.
- Parameters such as location, area, and intensity are drawn randomly from distributions based on historical data (reports, reanalyses, radar).

Draw year 2003 → **Simulate activity** Jan – Dec → **Repeat (10K)** 2011,1983, 1997,…

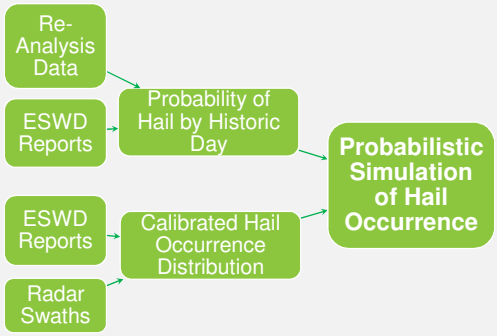


Hypothetical event

Challenges

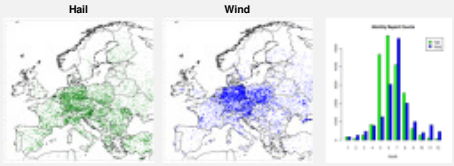
- Observations of hail occurrence are either
  - Incomplete (In-situ observations / storm reports)
  - Only available for a short timespan (radar data)
  - Indirect (re-analysis data, radar data)

Integration of Various Data Sources



Storm Reports

- European Severe Weather Database (ESWD, Dotzek et al. 2009a)
- Biased by population and country
- Positive temporal trend in reports until ~2005

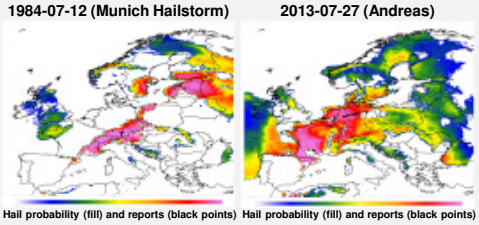


Locations of storm reports

Germany has the highest concentration of storm reports, followed by parts of Austria and Italy.

WRF Reanalysis

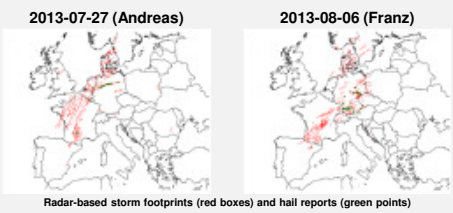
- Dynamically downscaled ERA-Interim to 16 km using WRF model
- Period 1979-2015
- Developed logistic regression to predict the conditional probability of hail based on environmental parameters (Mohr et al. 2015). Trained using storm reports in Germany.
  - $P(hail) = f(CAPE,\ Shear,\ WeatherType)$
  - $WeatherType = f(FlowDirection,\ Vorticity,\ Humidity)$
- Locations of simulated events in the stochastic catalog are based on random sampling from these reanalysis-based severe environments.



Radar

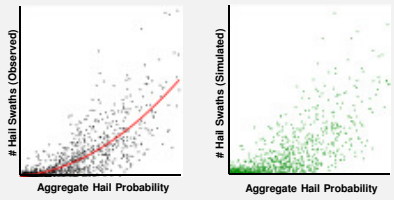
- Operational Program for Exchange of Weather Radar Information (OPERA, Huuskonen et al. 2014) European composite reflectivity mosaic.
- Grid spacing 2 km, temporal resolution 15 min, period 2010 – 2016.
- Storm identification and tracking algorithm produces historical hail swaths based on radar reflectivity threshold at each time step.

Radar



Radar-based storm footprints (red boxes) and hail reports (green points)

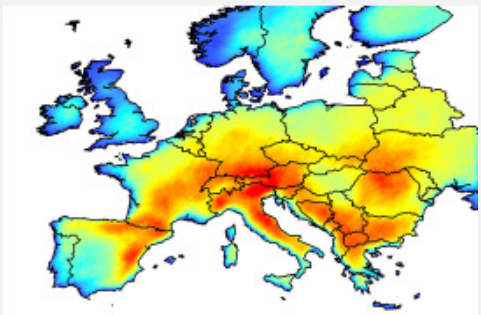
- Radar reflectivity does not guarantee hail occurrence. Calibration with ESWD data for population centers.
- Radar footprints inform stochastic events with regard to the distribution of convective initiation and the footprint attributes (length, width, intensity).



Summary

- Method is informed by different data sets to mitigate the weaknesses of the individual data sets.
- Convective initiation is simulated stochastically which captures the inherent uncertainty.
- The model will also capture the wind perils associated with severe thunderstorms (release planned 2018) and will complement AIR's EU Extra-tropical Cyclone model.

Simulated Hail Occurrence



Average hail occurrence frequency in a preliminary stochastic hail catalog of 1,000 years

References

Dotzek, N., P. Groenemeijer, B. Feuerstein, and A. M. Holzer, 2009a: Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD. *Atmos. Res.*, **93,** 575–586.

Huuskonen, A., E. Saltikoff, and I. Holleman, 2014: The operational weather radar network in Europe. *Bull. Amer. Meteor. Soc.*, **95,** 897-907.

Mohr, S., M. Kunz, and K. Keuler, 2015: Development and application of a logistic model to estimate the past and future hail potential in Germany. *J. Geophys. Res. Atmos.*, **120,** 3939-3956..