GUY CARPENTER

A catastrophe model of extreme hail events over Europe based on lightning observations.

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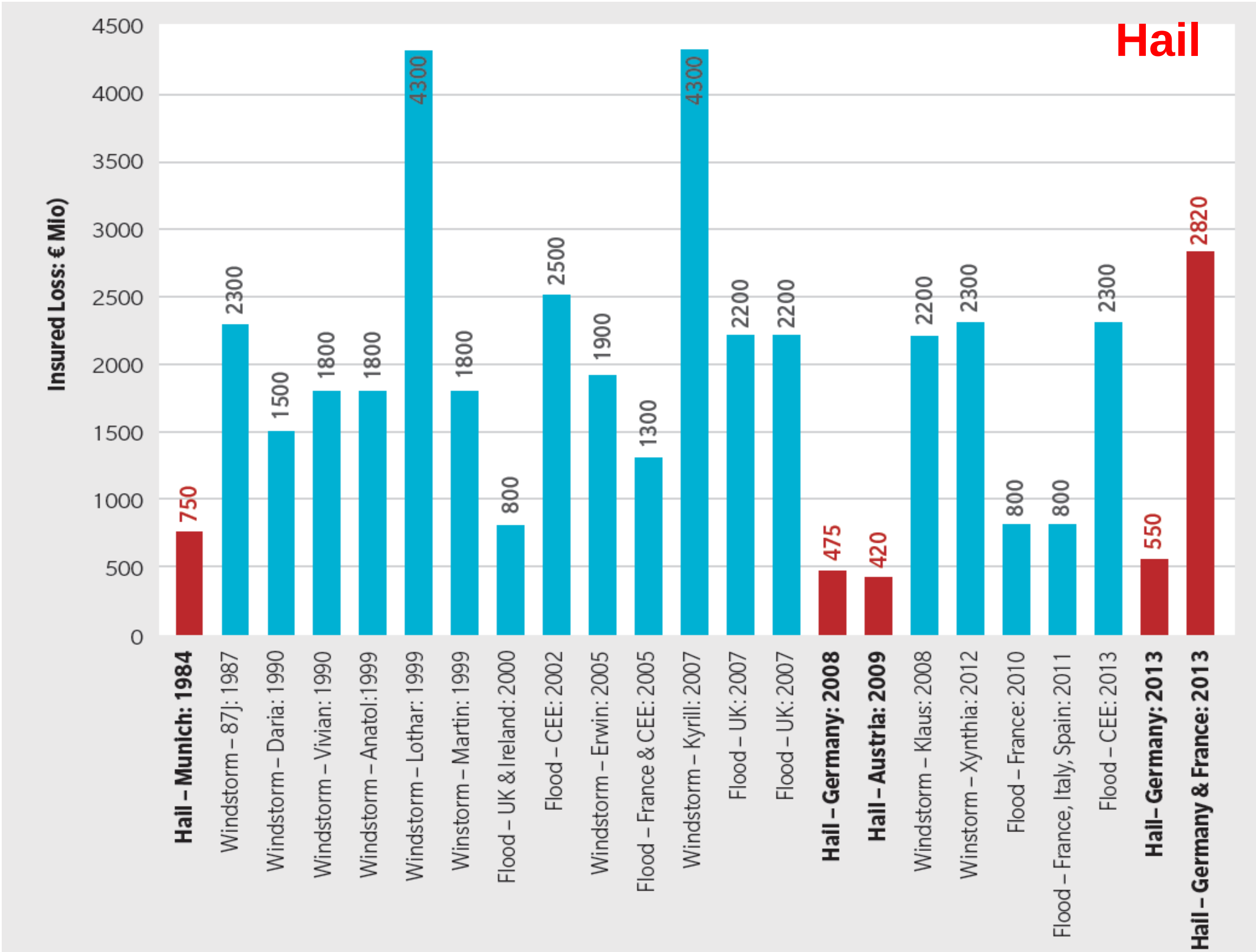
MARSH & McLENNAN COMPANIES

Introduction

- Guy Carpenter offers *reinsurance broking expertise*, *strategic advisory services*, and *industry-leading analytics*.
- We have developed a G-CAT® Continental Europe Hail Catastrophe Model for insurance risk management.
- I will present the hazard module of this model:
  - Estimating hail from lightning observations
  - Stochastic set generation method

Motivation: Hail storms in Europe

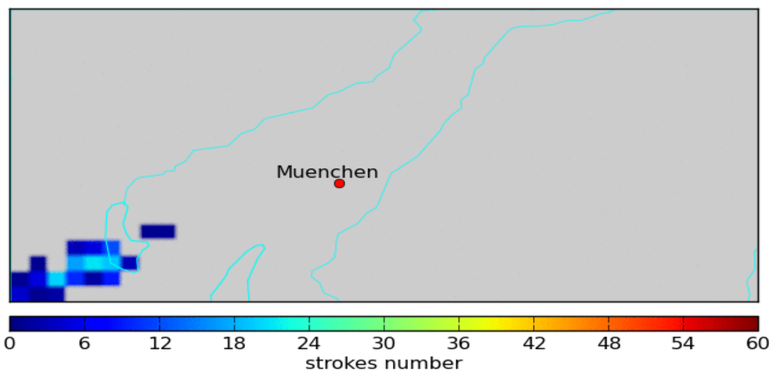
Cat events in the last 30 years

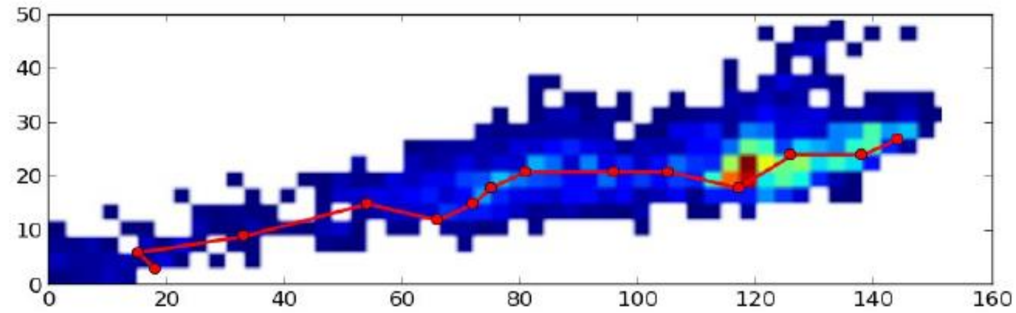


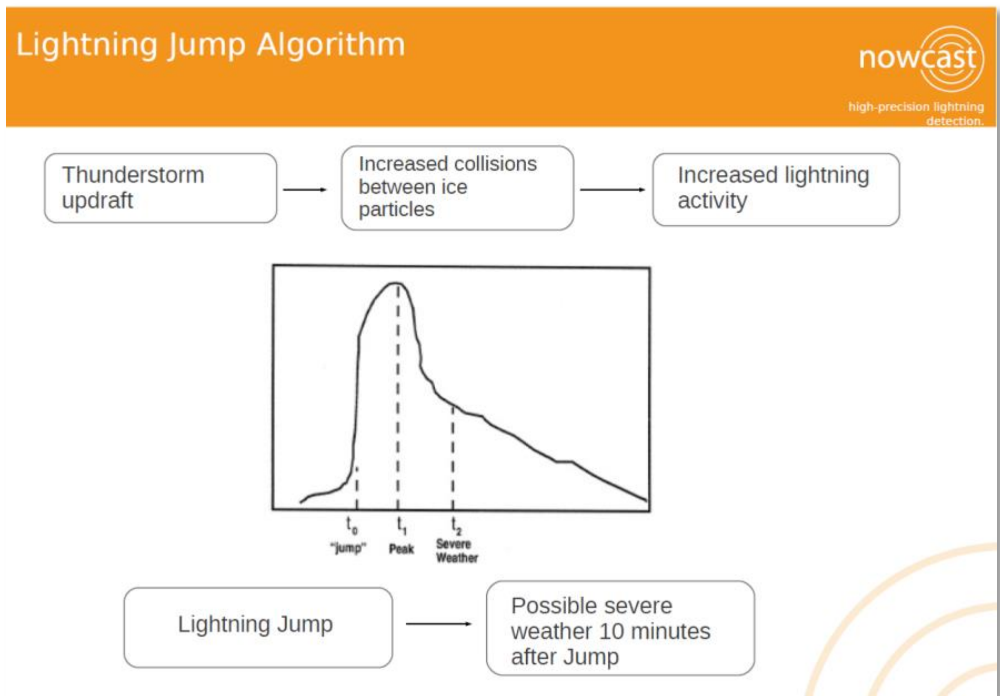
Identification of hail critical systems

Tracing of Lighting and Lightning Jumps

„tracing“ of convective cells



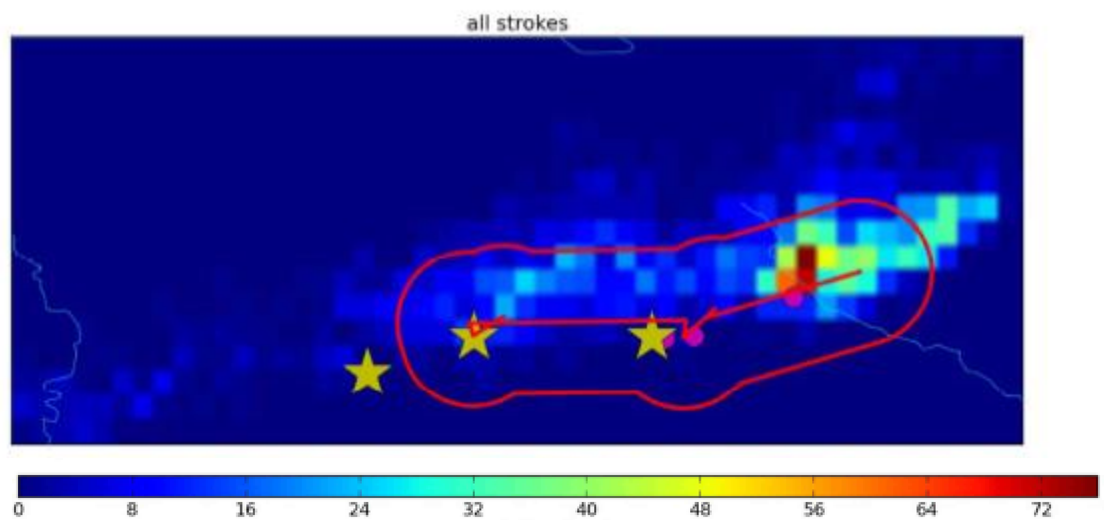




Identification of hail critical systems
Hail footprint definition

- *Nowcast GmbH* algorithm* uses lightning information to
  - compute a “hail” track
  - calculate the area of higher risk for hail.

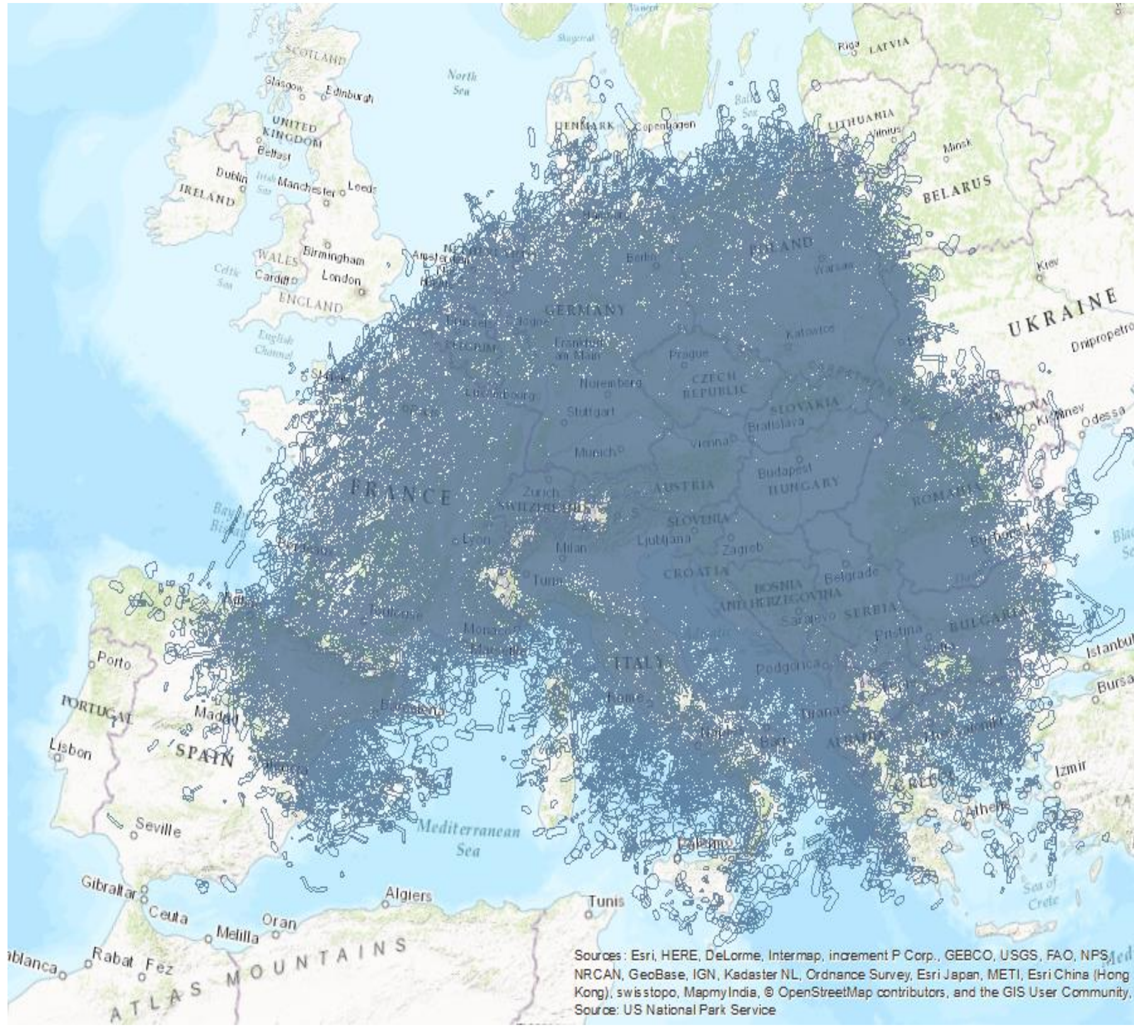
*United States Patent Application 20160299257



strokes density

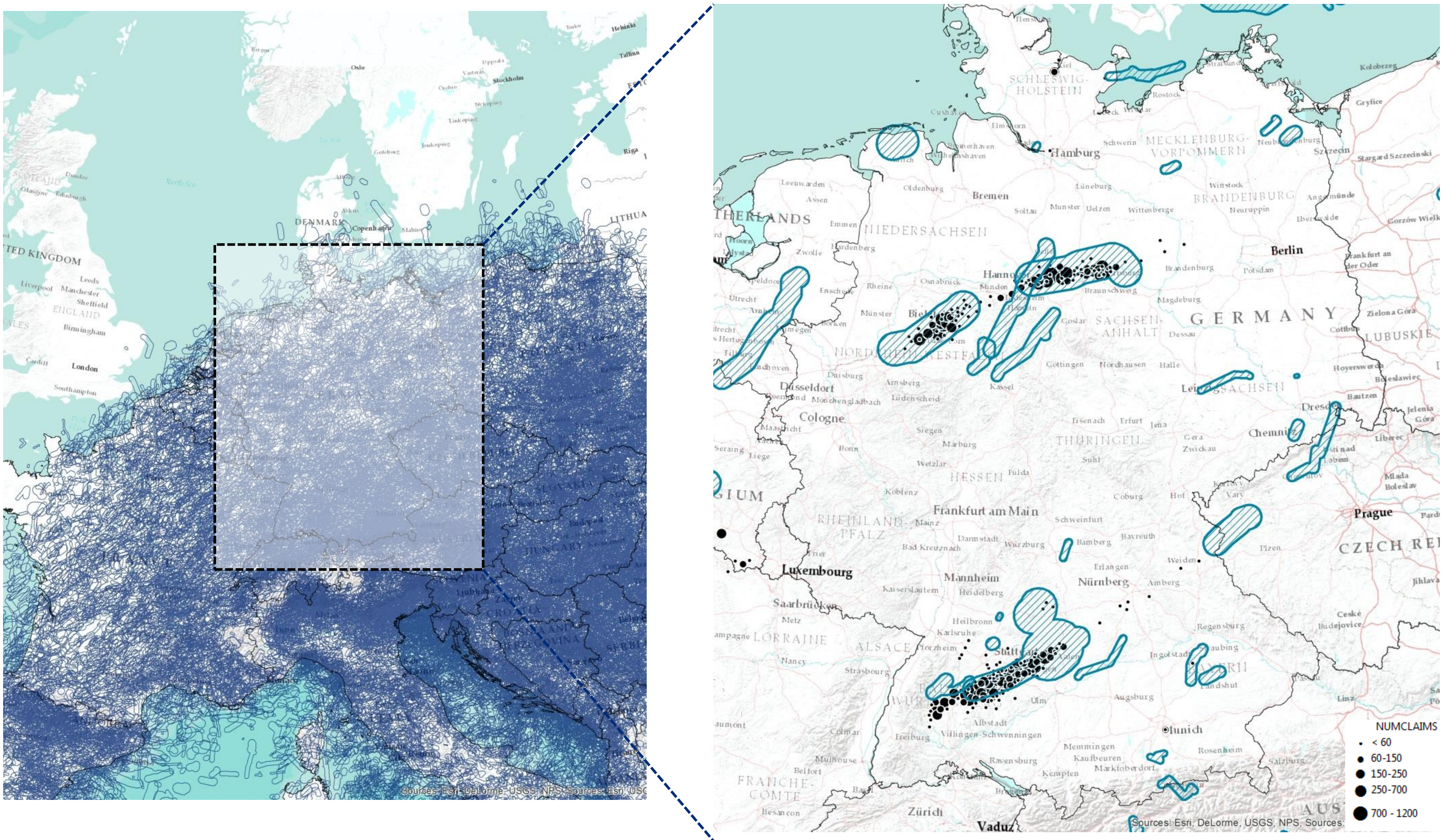
Historic Event Catalogue
Distribution of Historic Footprints

- Period: 2006-2015 (9 years)
- Total number of storm tracks: ~ 8,853
- Focusing on 12 countries in continental Europe (AT, BE, CH, CZ, DE, ES, FR, IT, LU, NL, PL, SI)
- For Spain, we used ESSL reports to fill up the data gap.



Historic Event Catalogue

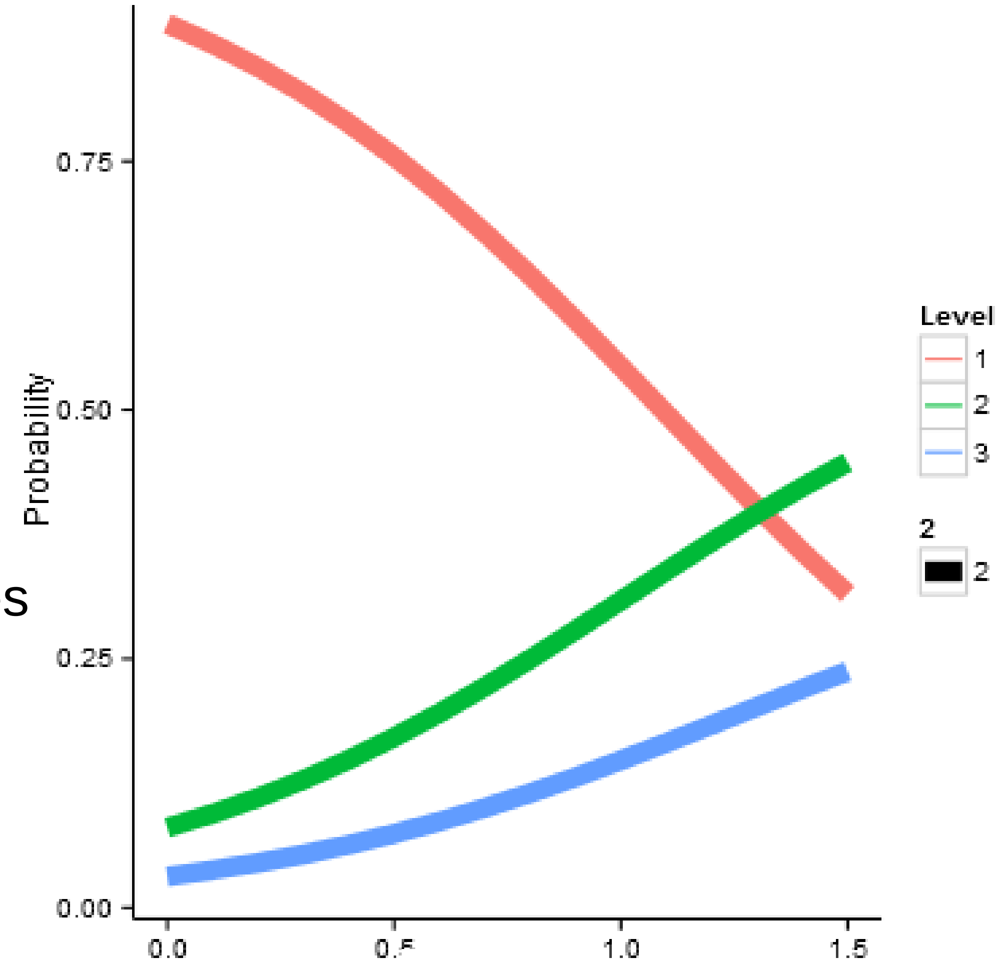
Hail storm Andreas, 27 and 28 July 2013



Severity
Hail footprint intensity

- Use ESSL data to define **three intensity bins**:
  - [2 - 6) cm : ESSL-Intensity 1
  - [6 - 8) cm : ESSL-Intensity 2
  - [8 - ∞) cm : ESSL-Intensity 3
- Match ESSL with nowcast by date and by location.
- Fit a logistic model **between the footprint area and the ESSL-Intensity**: the mean area increases with ESSL-Intensity.

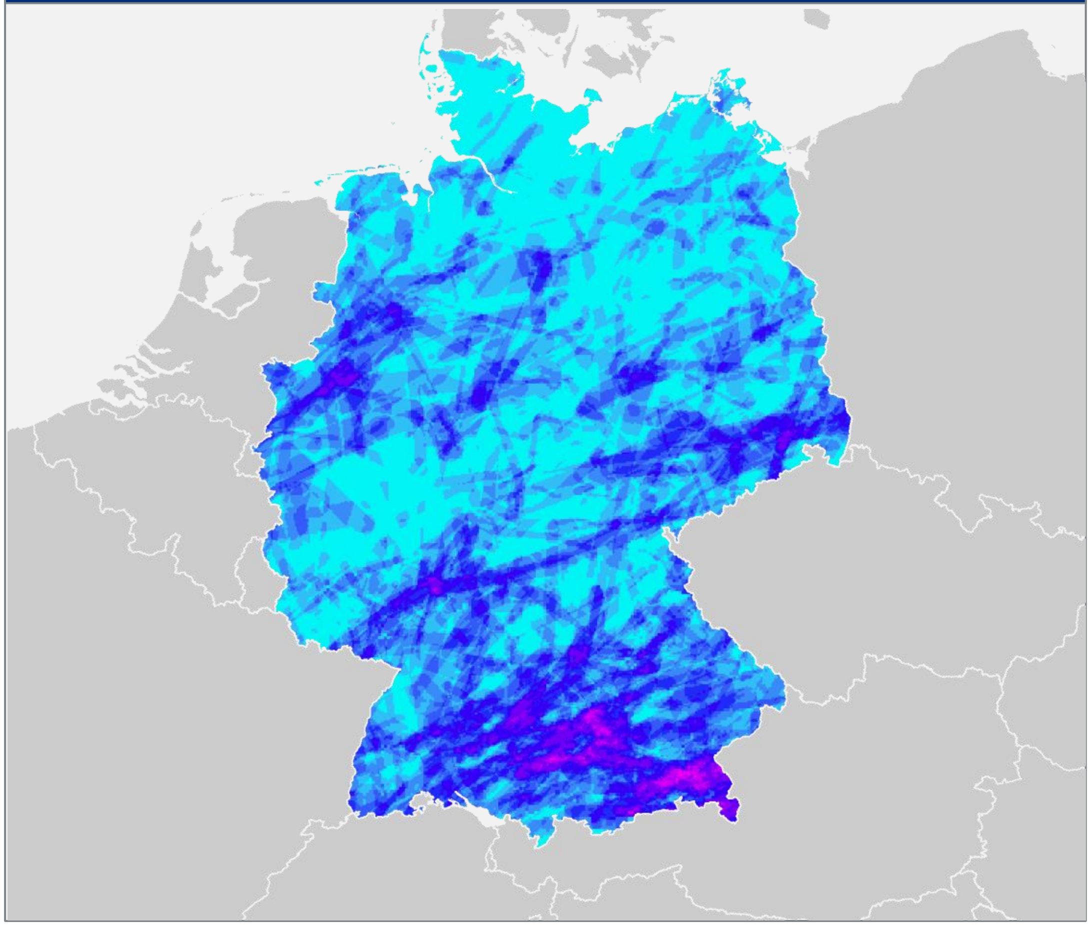
Probability



area

Stochastic modelling
Simulation of Synthetic Events

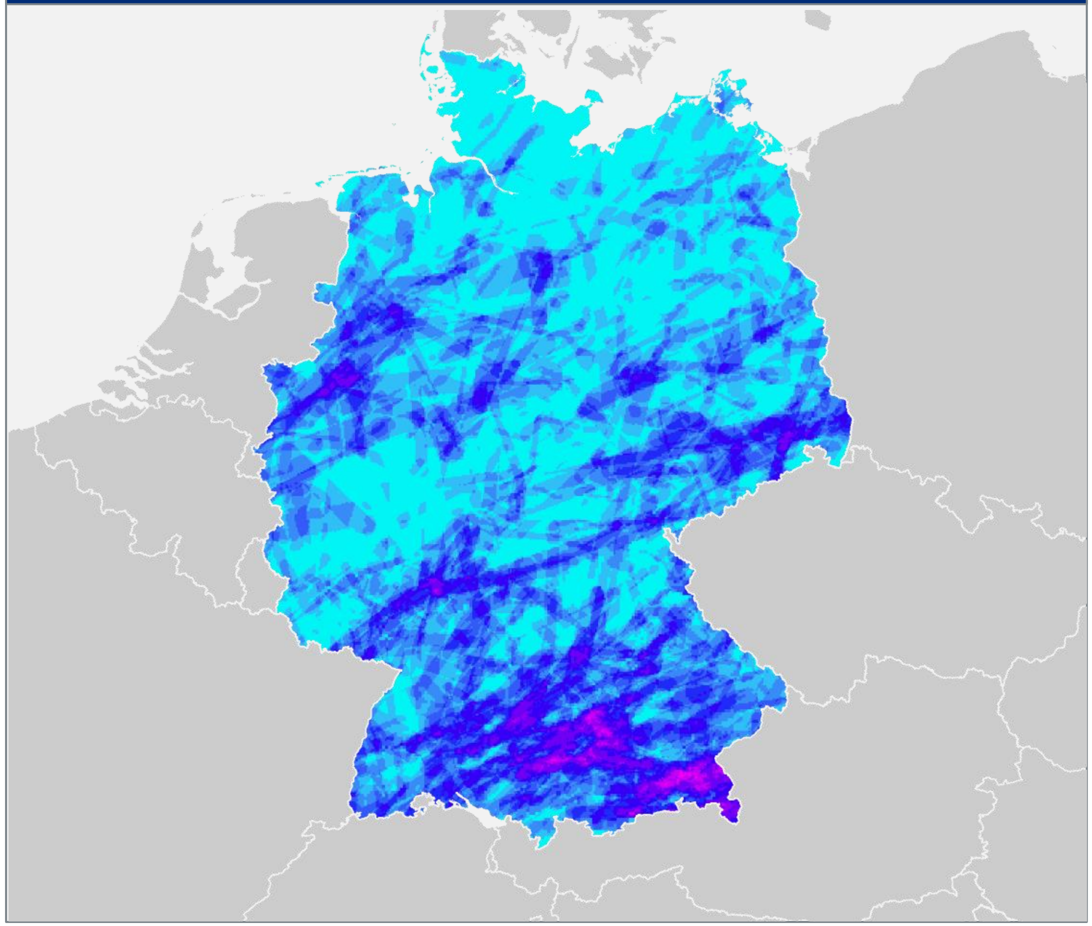
Origin: historic event catalogue and hazard map



Stochastic modelling
Simulation of Synthetic Events

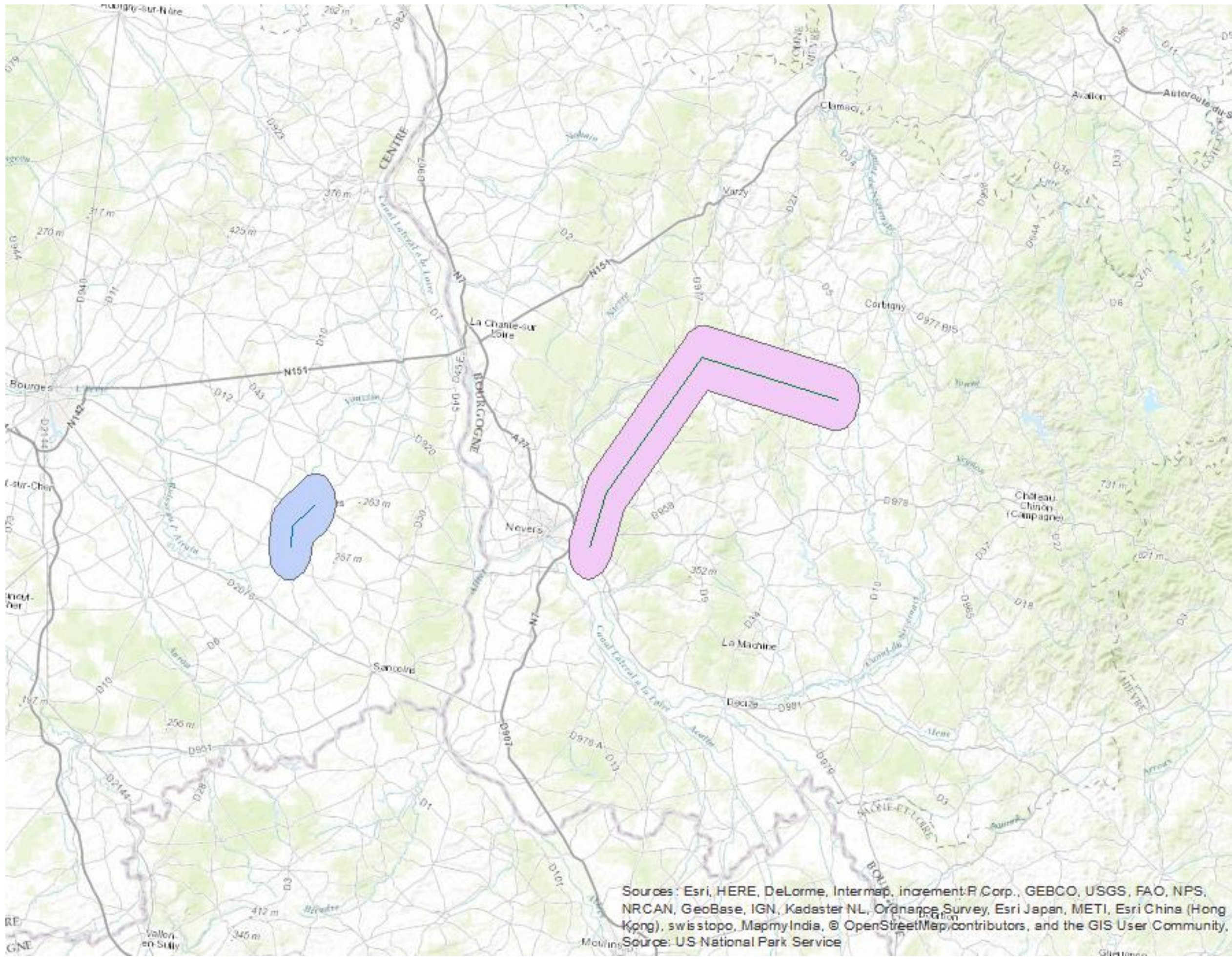
Identify hail storm track attributes

Origin: historic event catalogue and hazard map



Identify hail storm track attributes

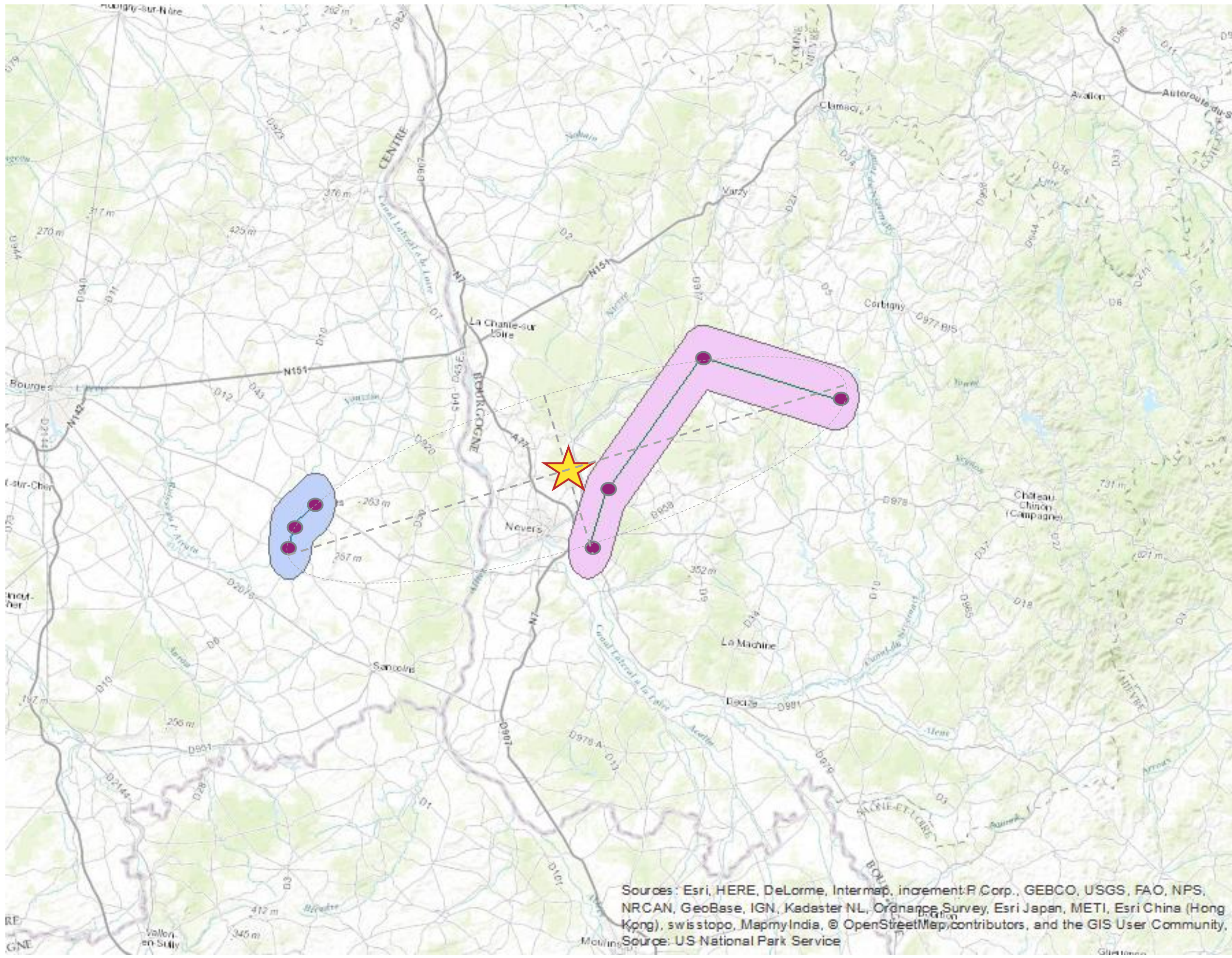
- Storm centre
- Bearing
- Total length



Identify hail storm track attributes

The ellipses are **only** used to define the centre point and the direction of the storm track

- **Storm centre**
- Bearing
- Total length



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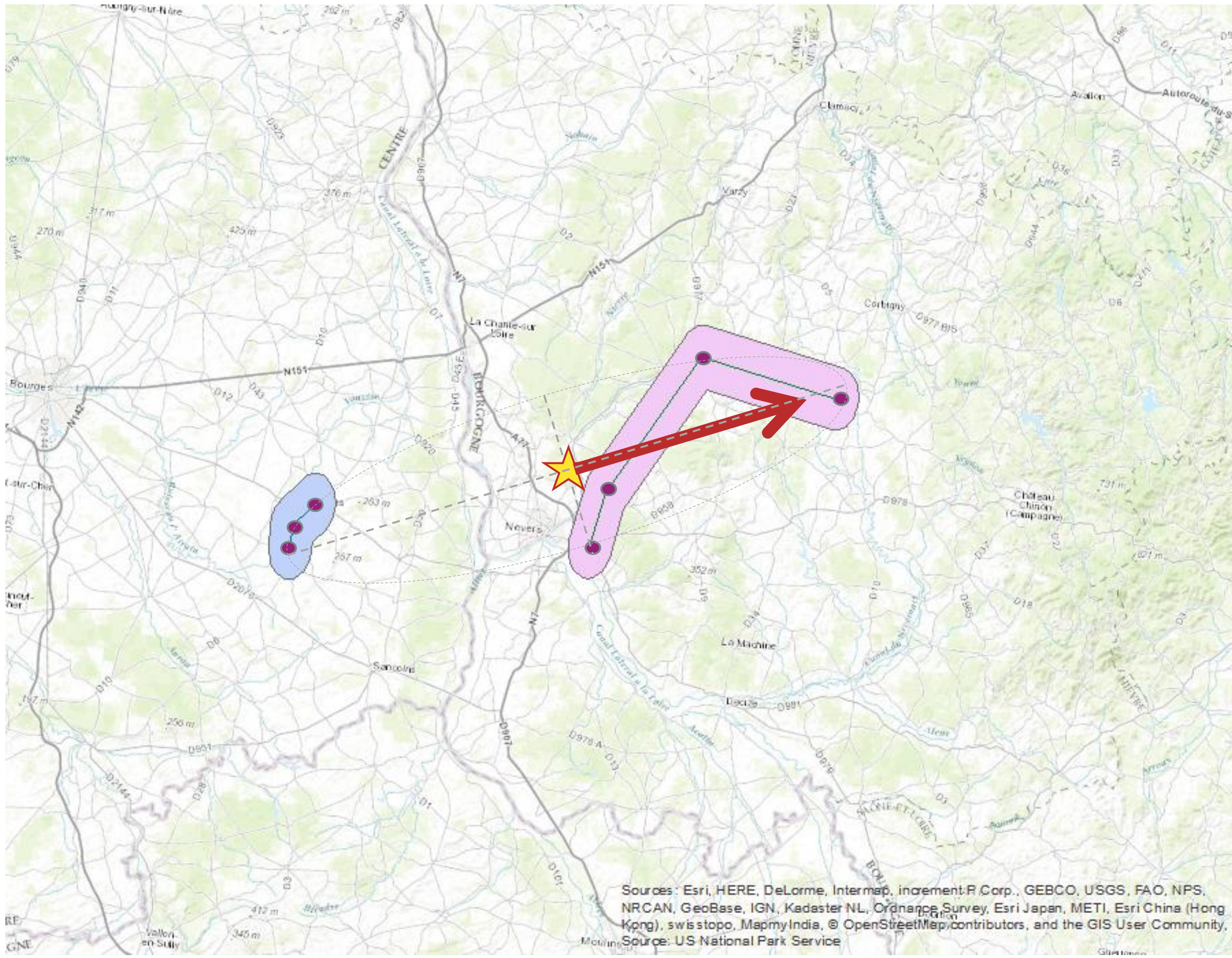

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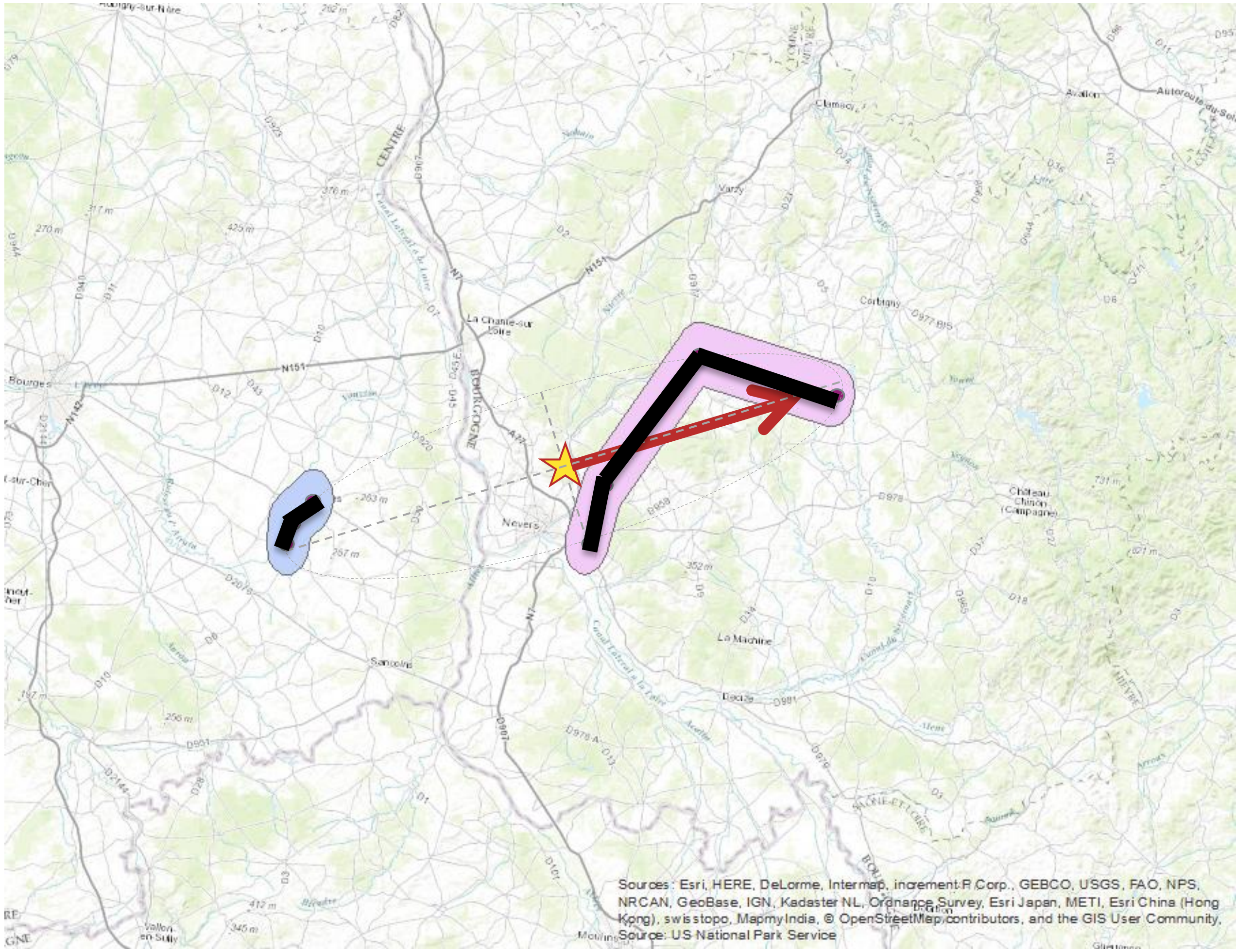
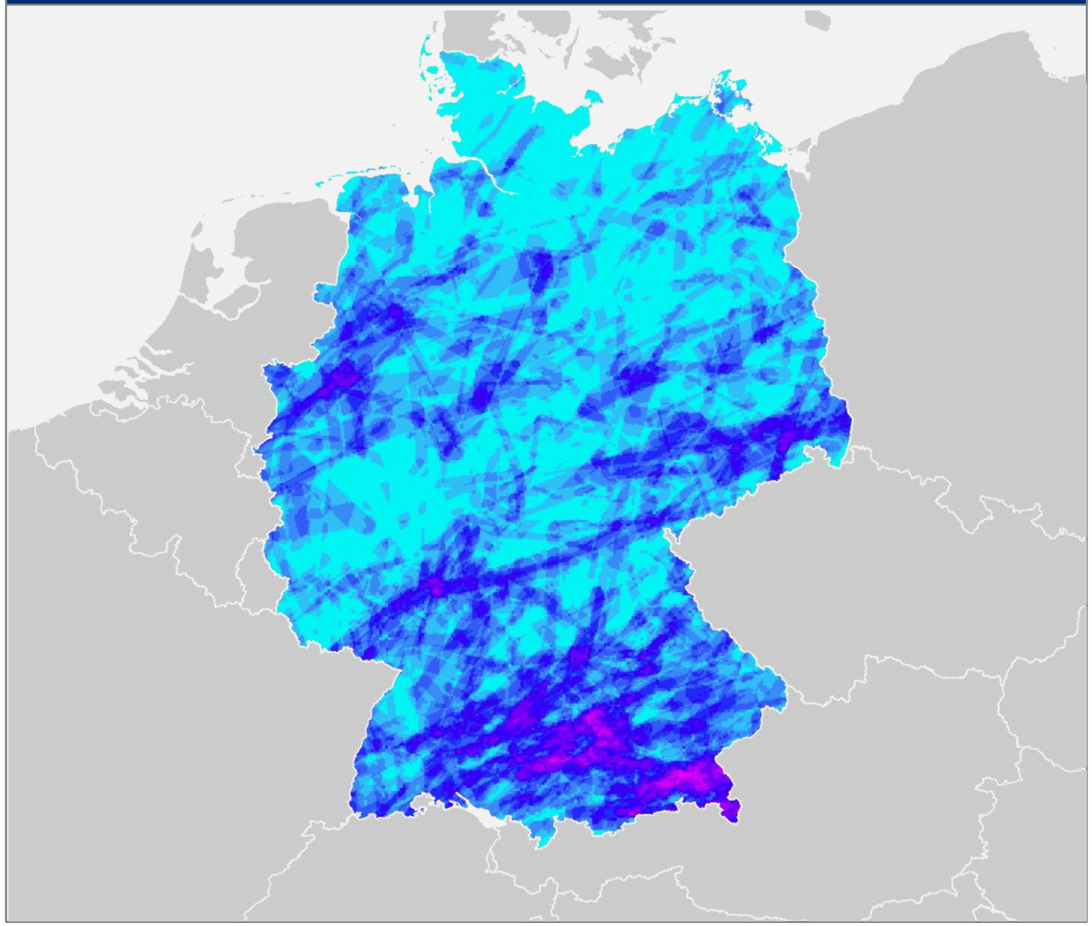


Stochastic modelling
Simulation of Synthetic Events

Identify hail storm track attributes

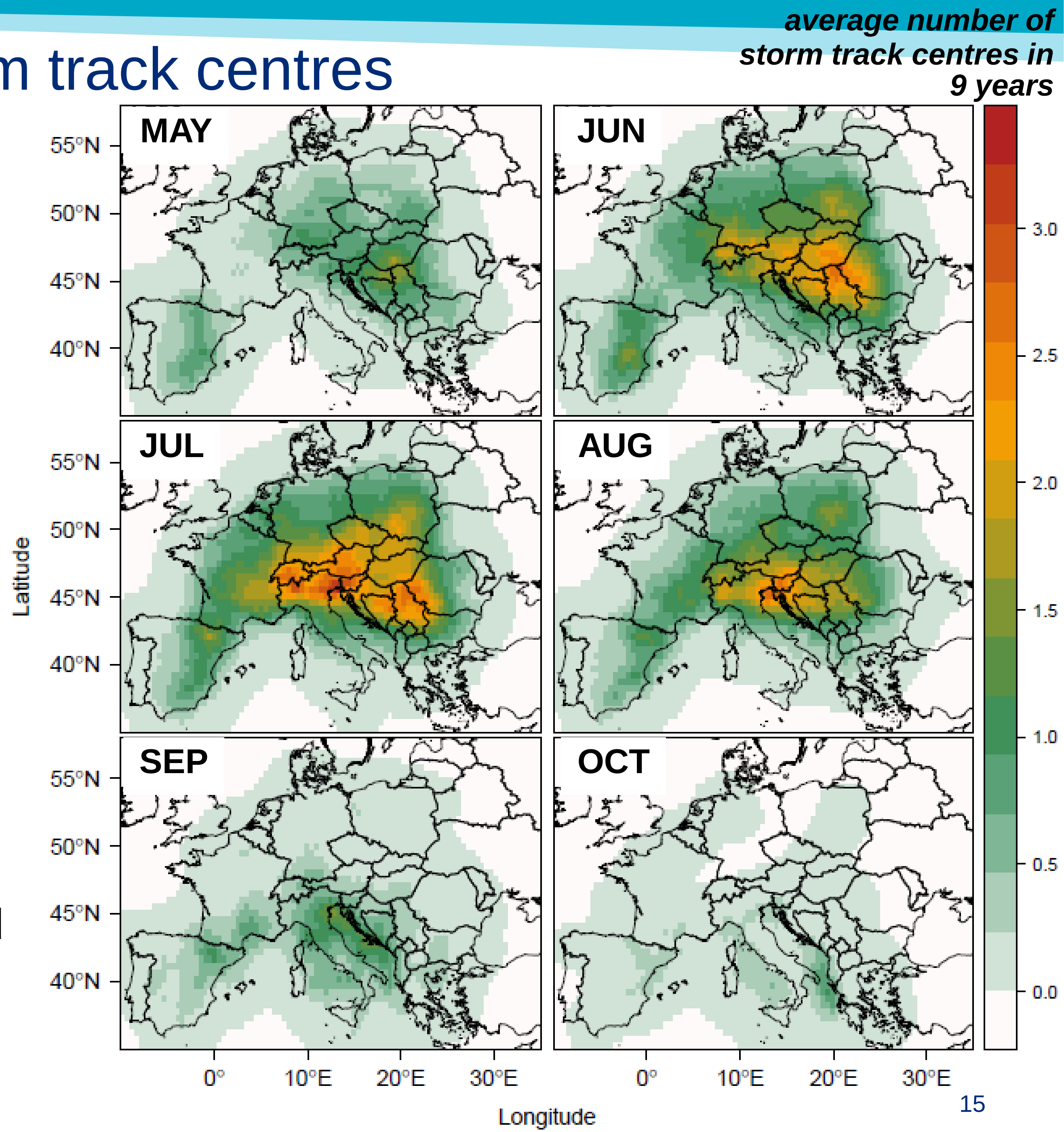
Fit a model for each attribute at each grid cell

Origin: historic event catalogue and hazard map



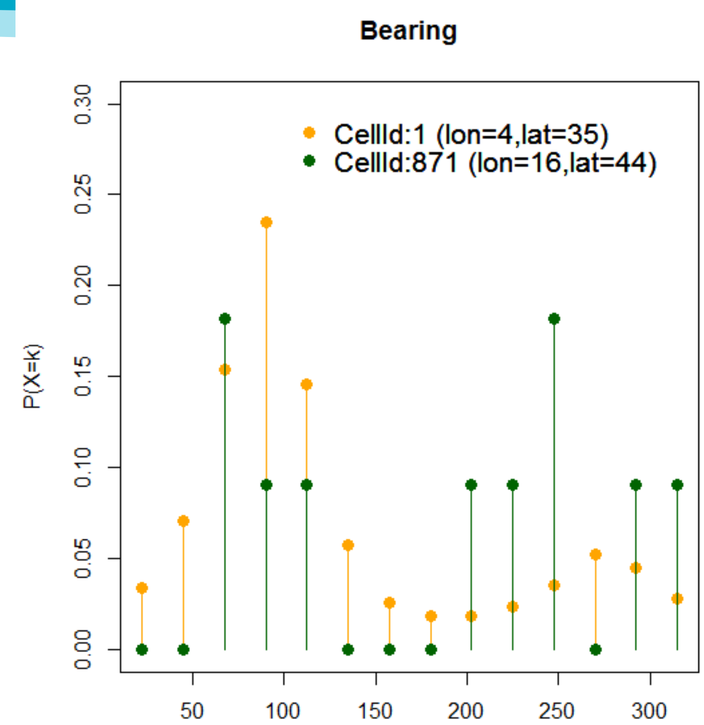
Fit a model of storm track centres

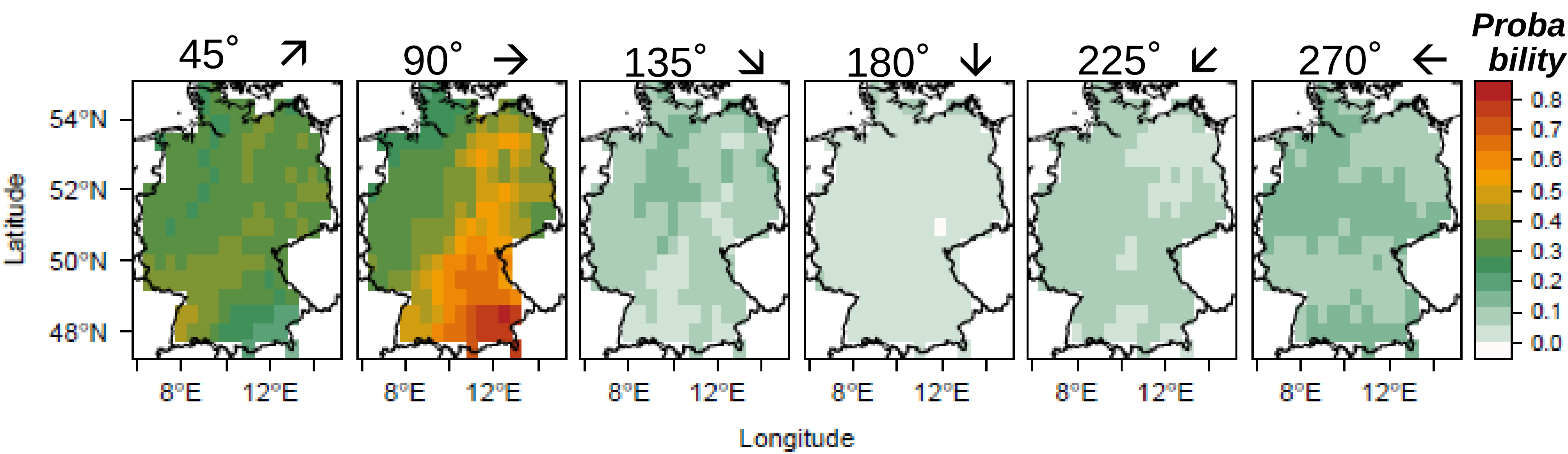
- Historical storm centres density map on a 0.5x0.5 grid.
- Fit a Poisson model (with intercept only) for each grid cell
  - $\log\lambda = \alpha$
- Taking more into account the influence of the neighbouring cells weighting with distance: exp(-distance/K)
- K is set to 64km, estimated with out-of-sample likelihoods



Fit a model for the bearing

- An *empirical* approach is chosen: for each grid cell, the storms located within a ~150km radius are selected.
- In order to accurately represent the observed **bimodal** distribution of bearing angles



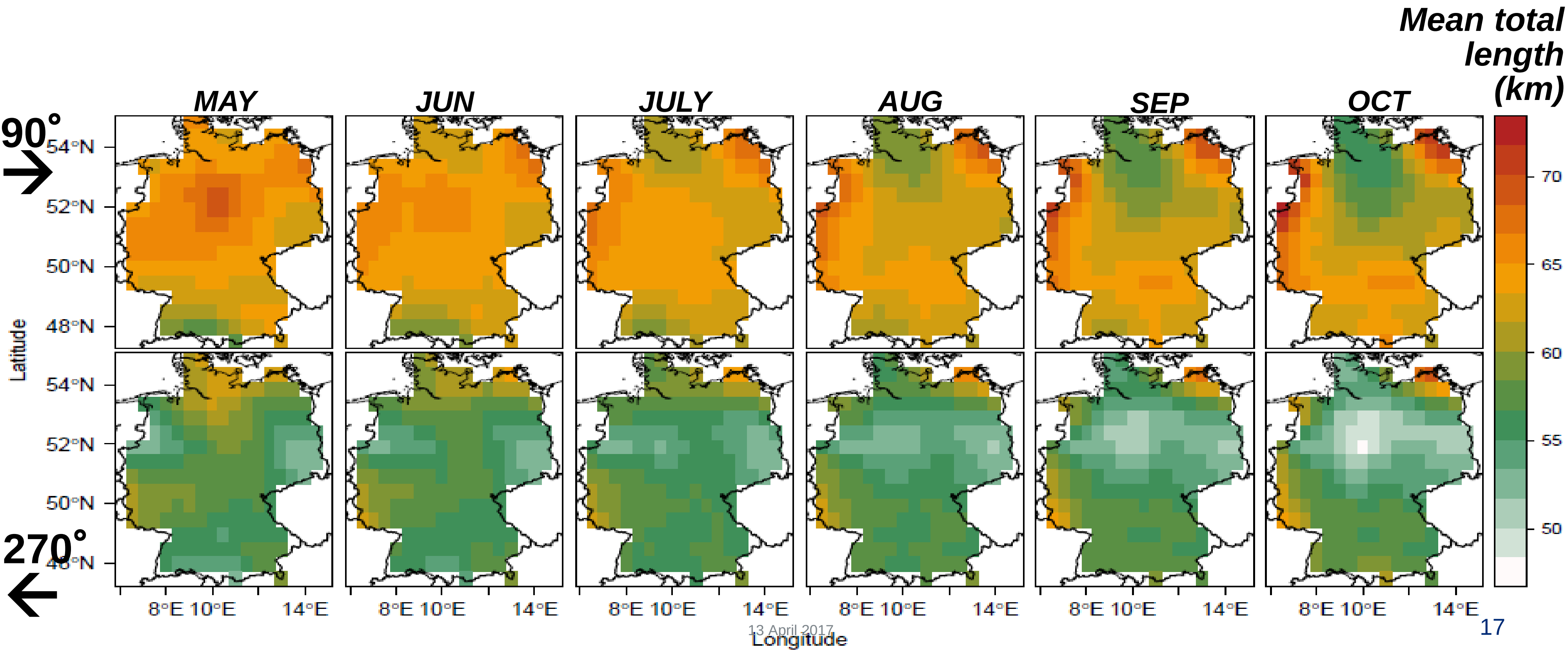


Fit a model for the storm total length

- Linear model with two predictors. For each grid cell:

$$\text{Log}\mathbf{L} = \text{alpha} + \text{beta} * \mathbf{season} + \text{gamma} * \mathbf{bearing}$$

- Take into account the influence of the neighbouring cells weighting with distance: exp(-distance/K).



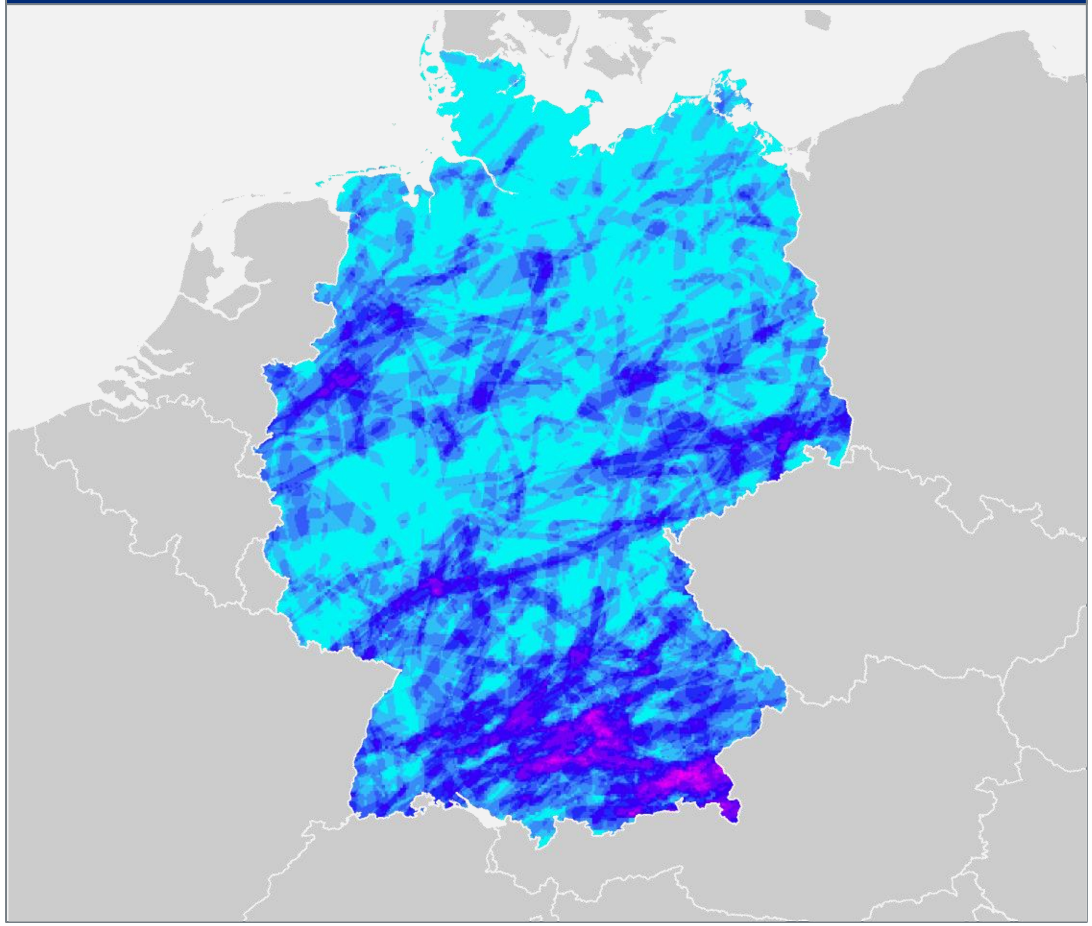
Stochastic modelling
Simulation of Synthetic Events

Identify hail storm track attributes

Fit a model for each attribute at each grid cell

Simulate stochastic events

Origin: historic event catalogue and hazard map



Simulate stochastic events

- We generate a simulation of synthetic storms based on the fitted attributes (storm track centre, bearing, total storm length)
- We simulate 200 blocks of 9 years, i.e. 1800 years in total.

Stochastic modelling
Simulation of Synthetic Events

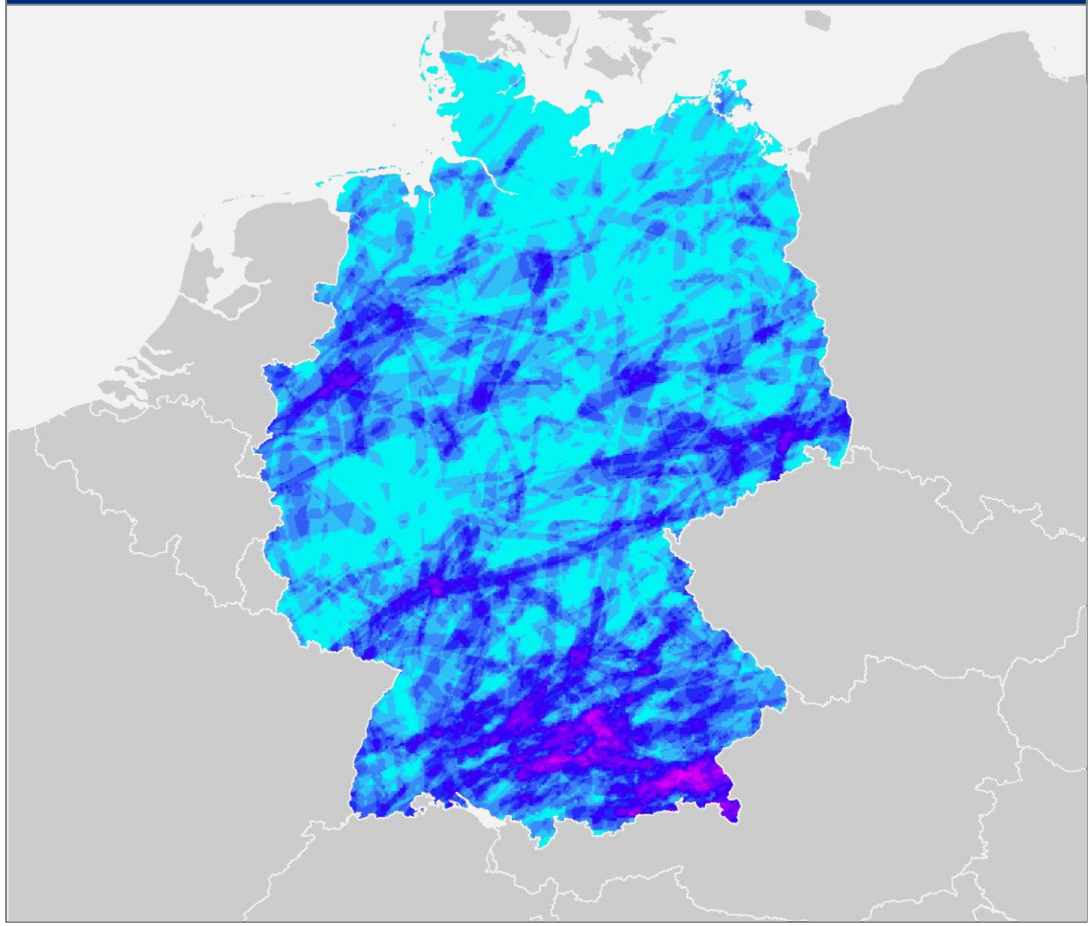
Identify hail storm track attributes

Fit a model for each attribute at each grid cell

Simulate stochastic events

Assign historical hail storm track to the stoc. events using *bootstraping*.

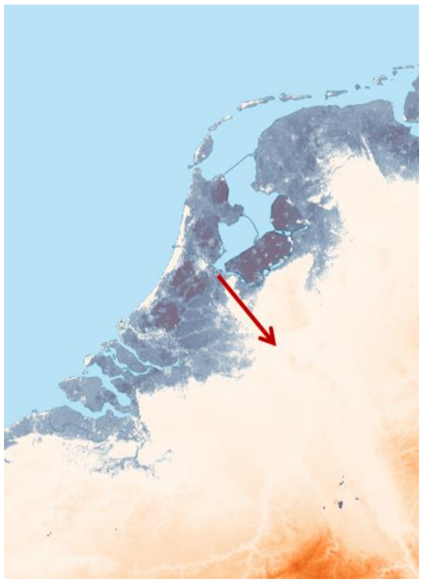
Origin: historic event catalogue and hazard map



Bootstrapping

- For each synthetic hail storm,

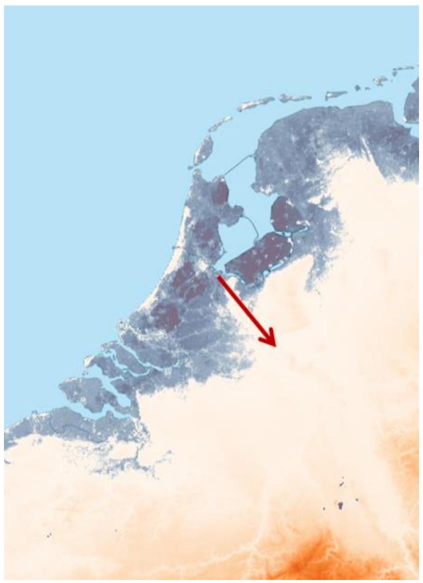
Simulated storm attributes



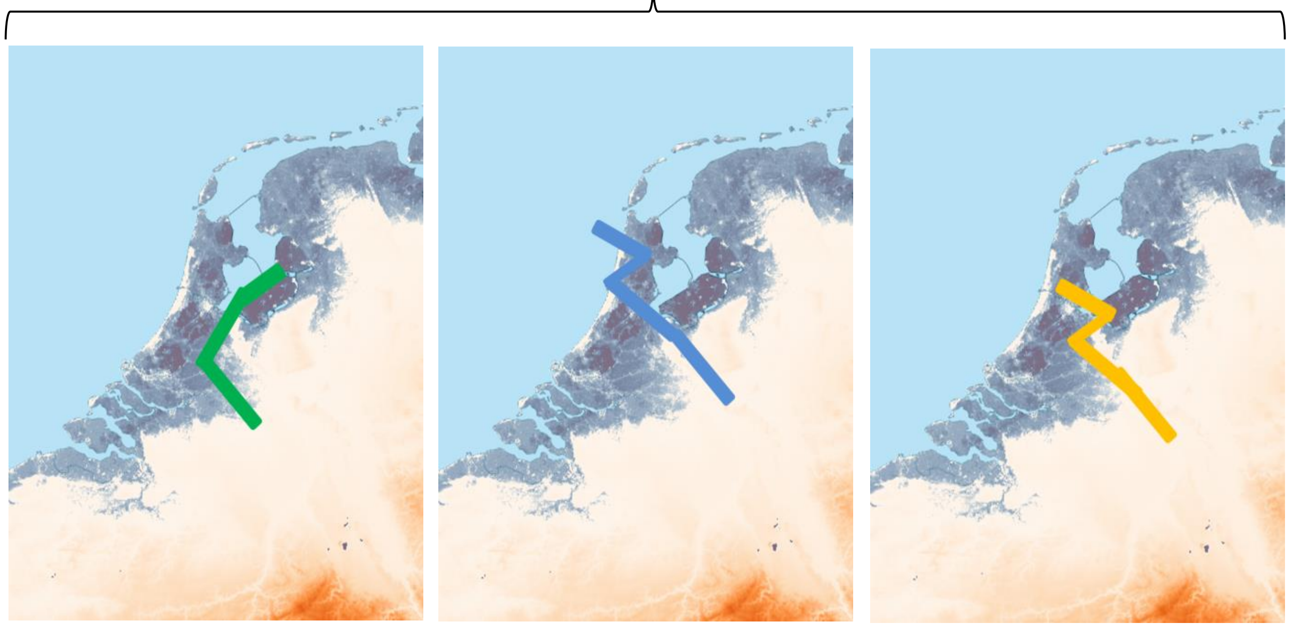
Bootstrapping

- For each synthetic hail storm, select a group of historical storms that fall within the same length bin and rotate/move accordingly.

Simulated storm attributes



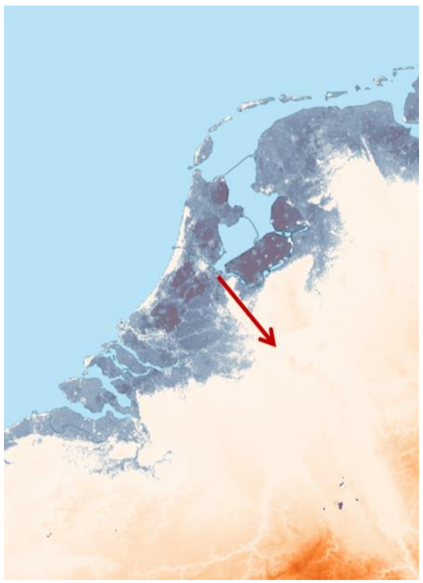
Historical storms with similar length



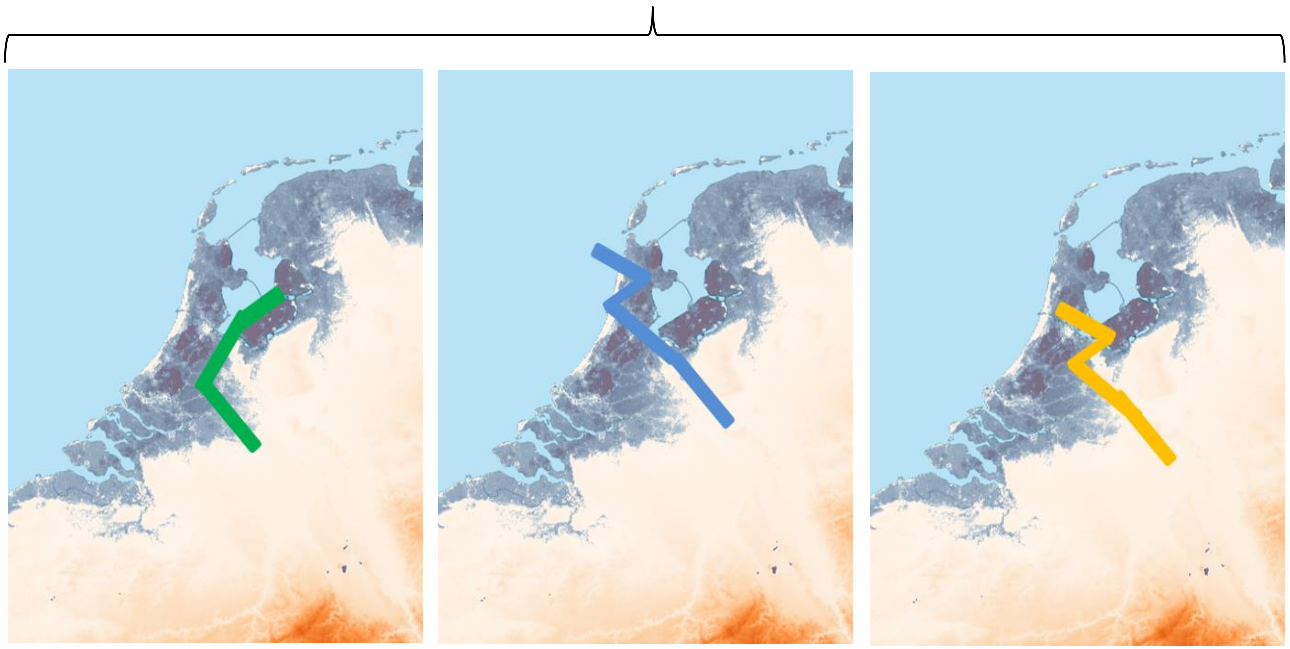
Bootstrapping

- For each synthetic hail storm, select a group of historical storms that fall within the same length bin and rotate/move accordingly.
- Compute probability weights for each candidate storm based on the historically observed density of track vertices.

Simulated storm attributes



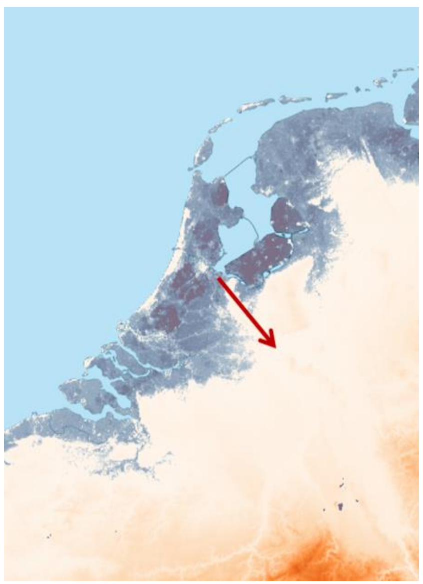
Historical storms with similar length



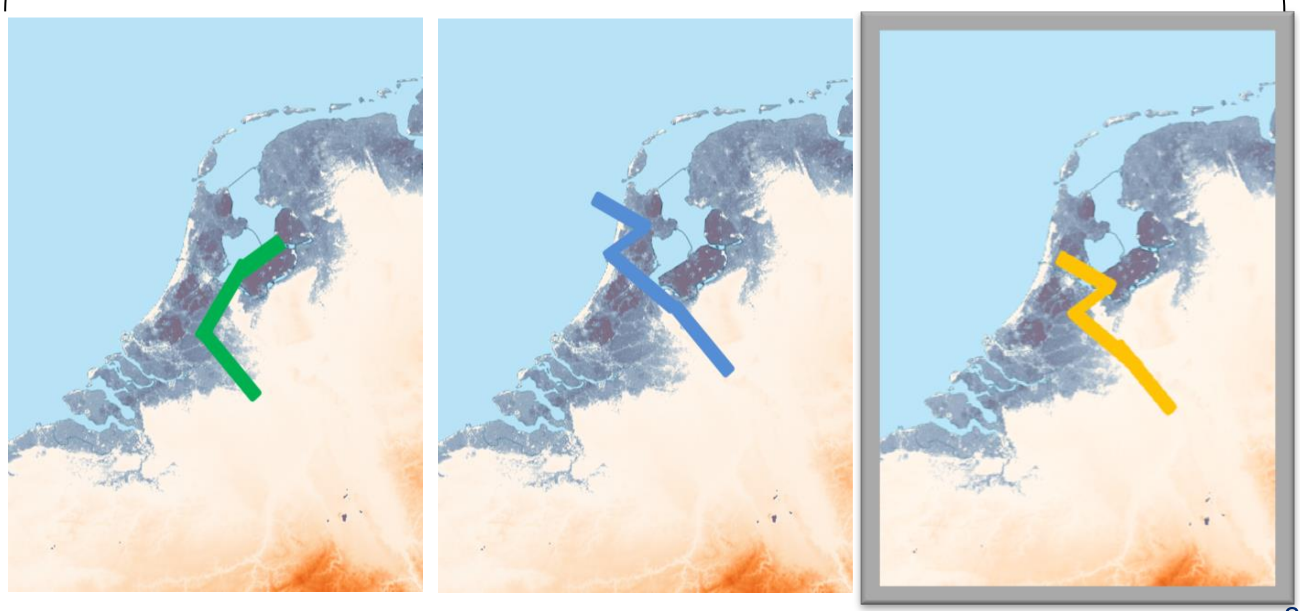
Bootstrapping

- For each synthetic hail storm, select a group of historical storms that fall within the same length bin and rotate/move accordingly.
- Compute probability weights for each candidate storm based on the historically observed density of track vertices.
- **Sample** from the candidate storms based on those weights

Simulated storm attributes



Historical storms with similar length



Bootstrapping

- Advantages:
  - Preserve the track shapes of severe convective storms
    - Realistic simulated hail tracks - footprints
  - Simplicity

Stochastic modelling
Simulation of Synthetic Events

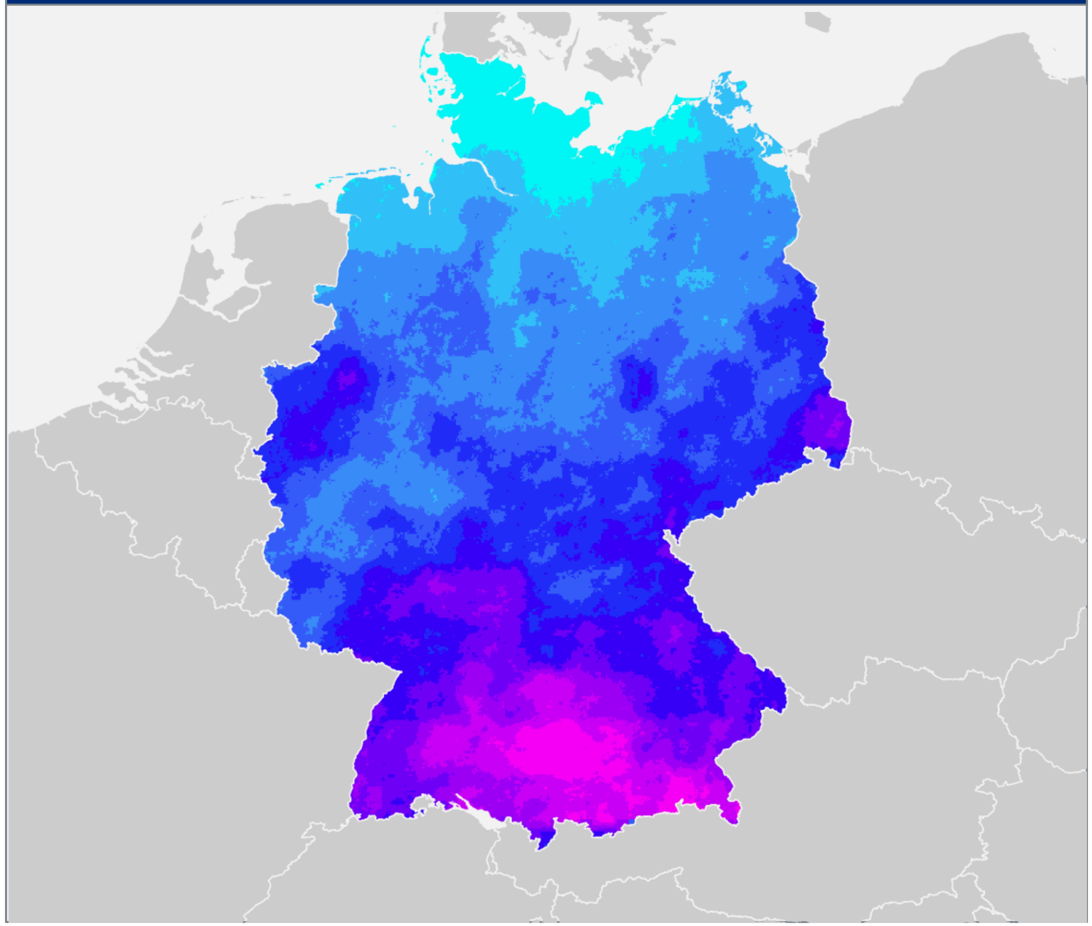
Identify hail storm track attributes

Fit a model for each attribute at each grid cell

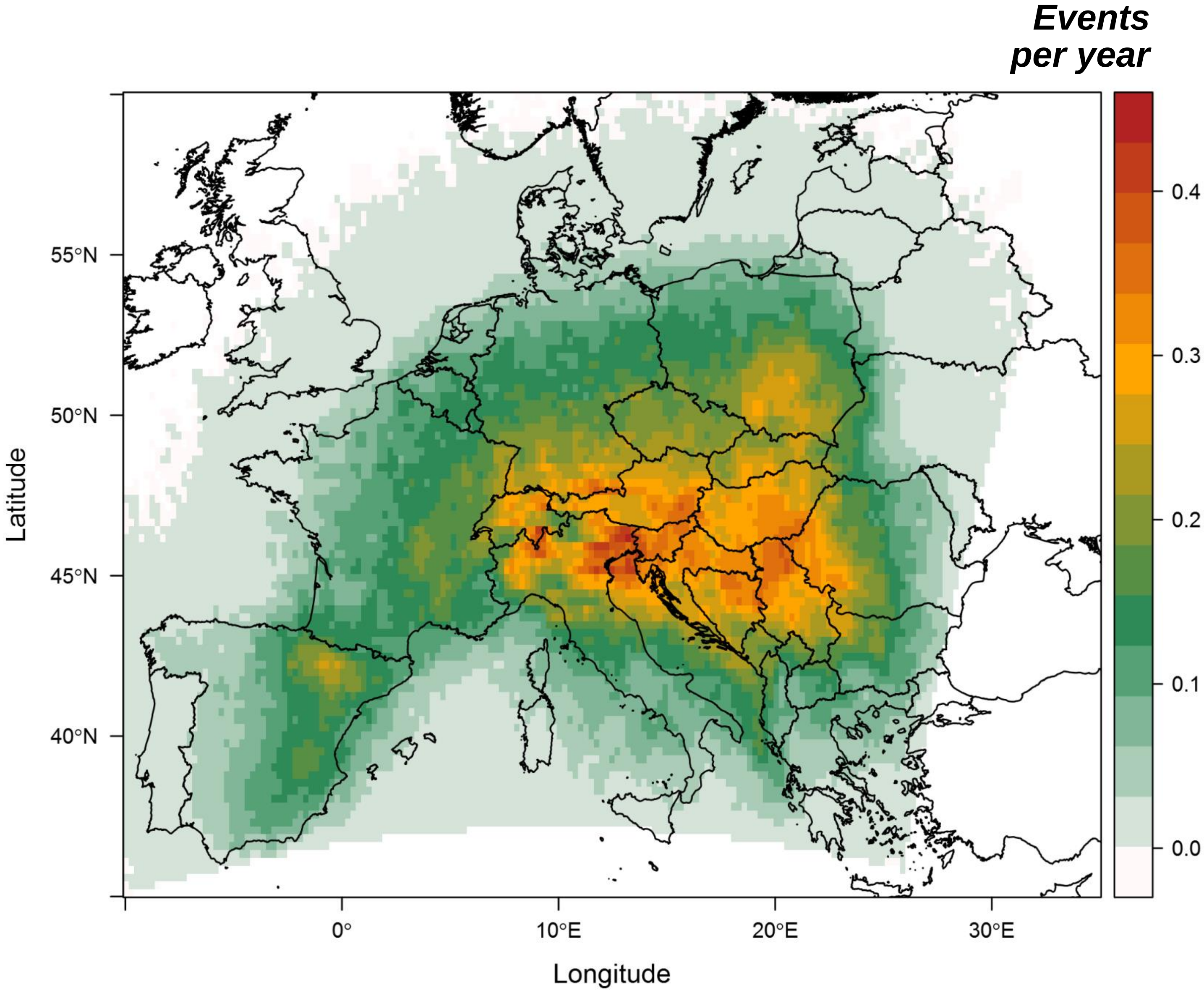
Simulate stochastic events

Assign historical hail storm track to the stoc. events using *bootstraping*.

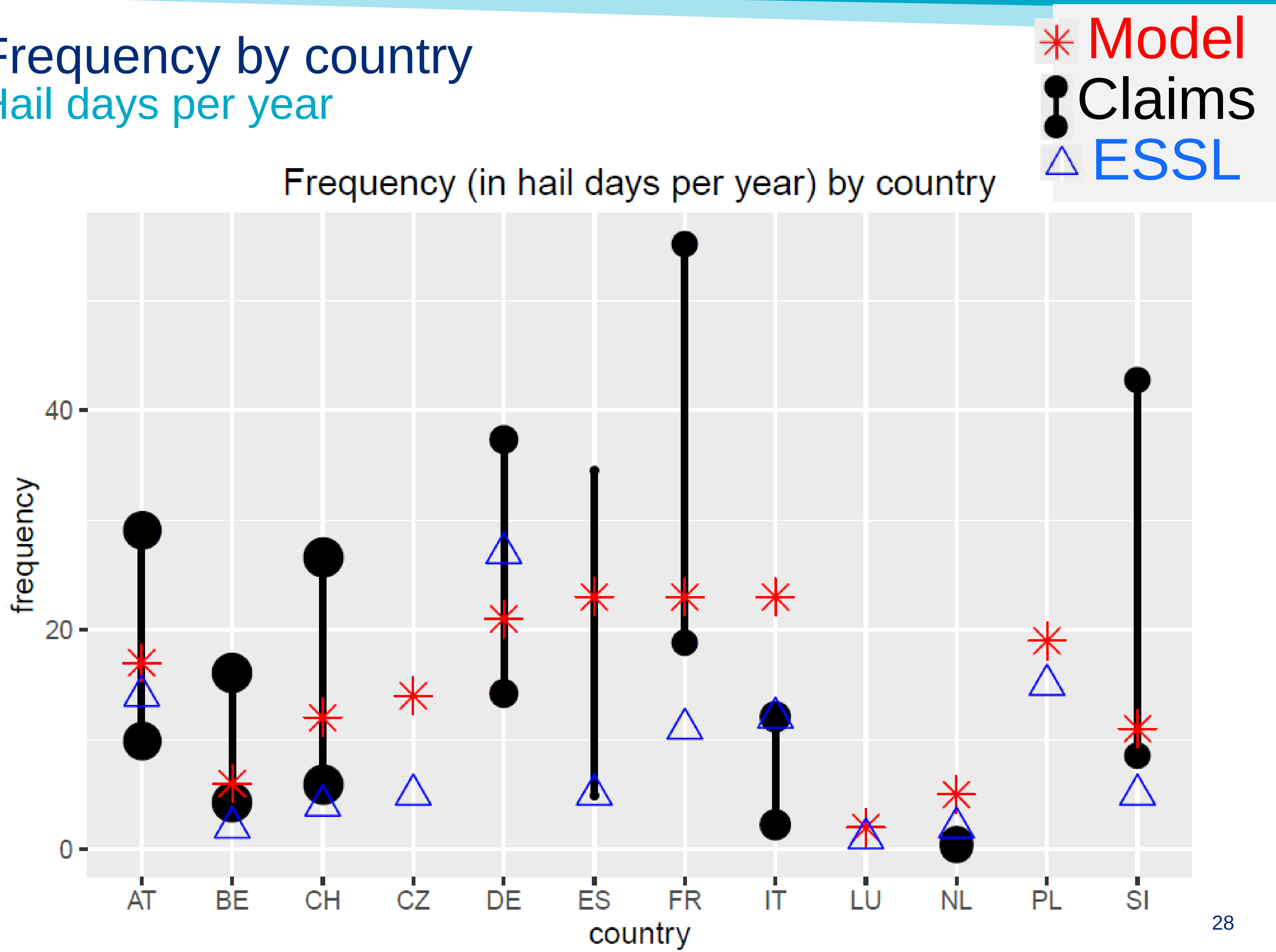
Result: stochastic catalogue and hazard map



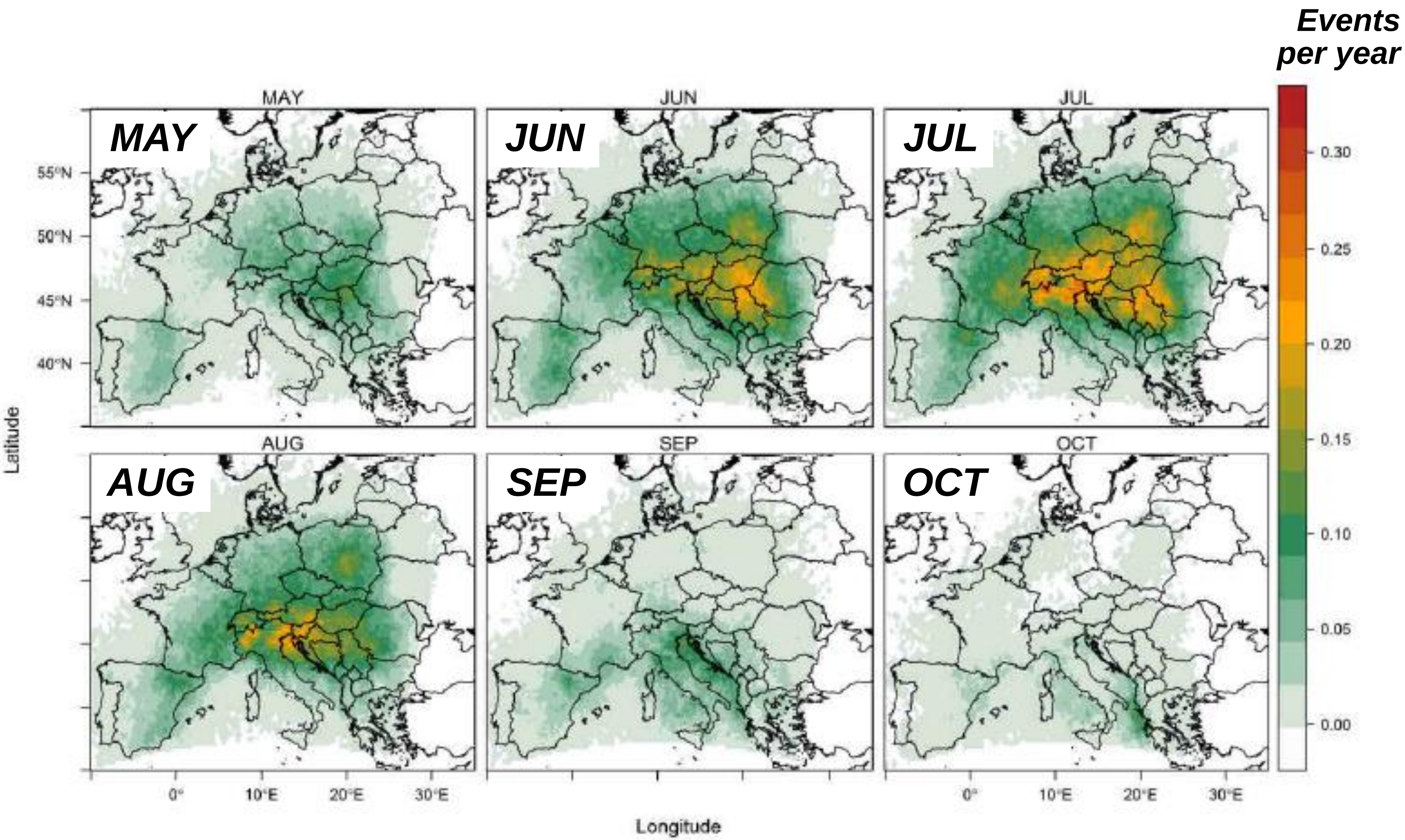
Hazard maps
All events



Frequency by country
Hail days per year

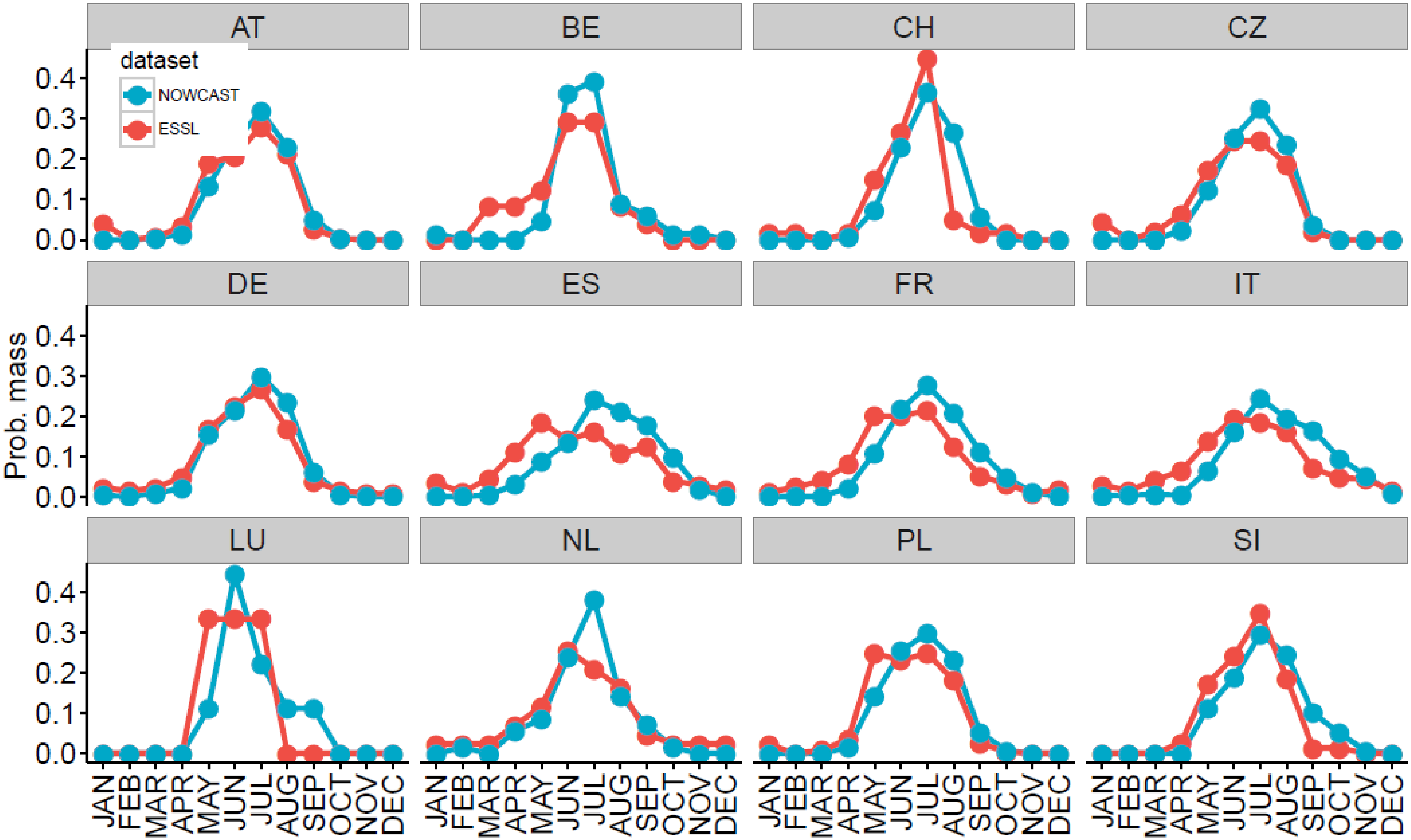


Hazard maps
Seasonal variation



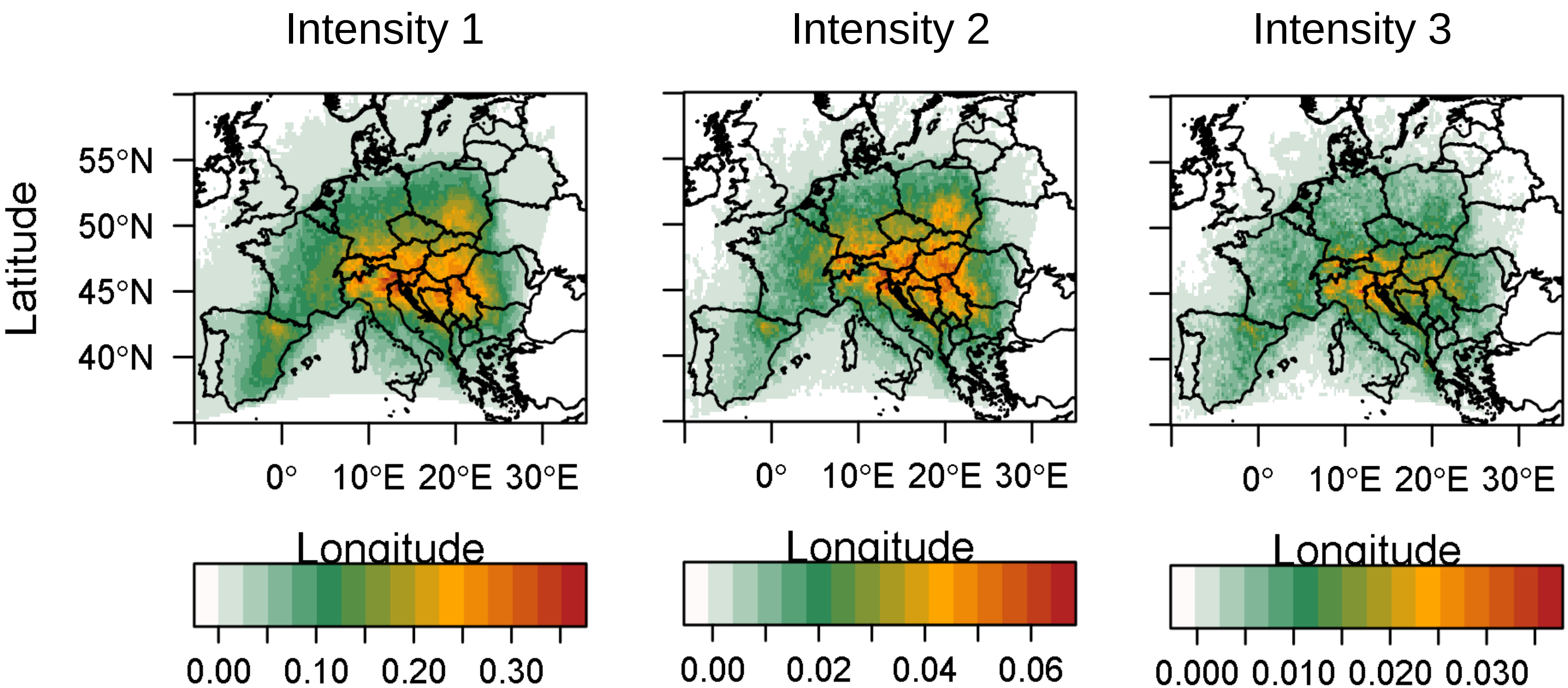
Seasonal variation

Model vs. ESSL

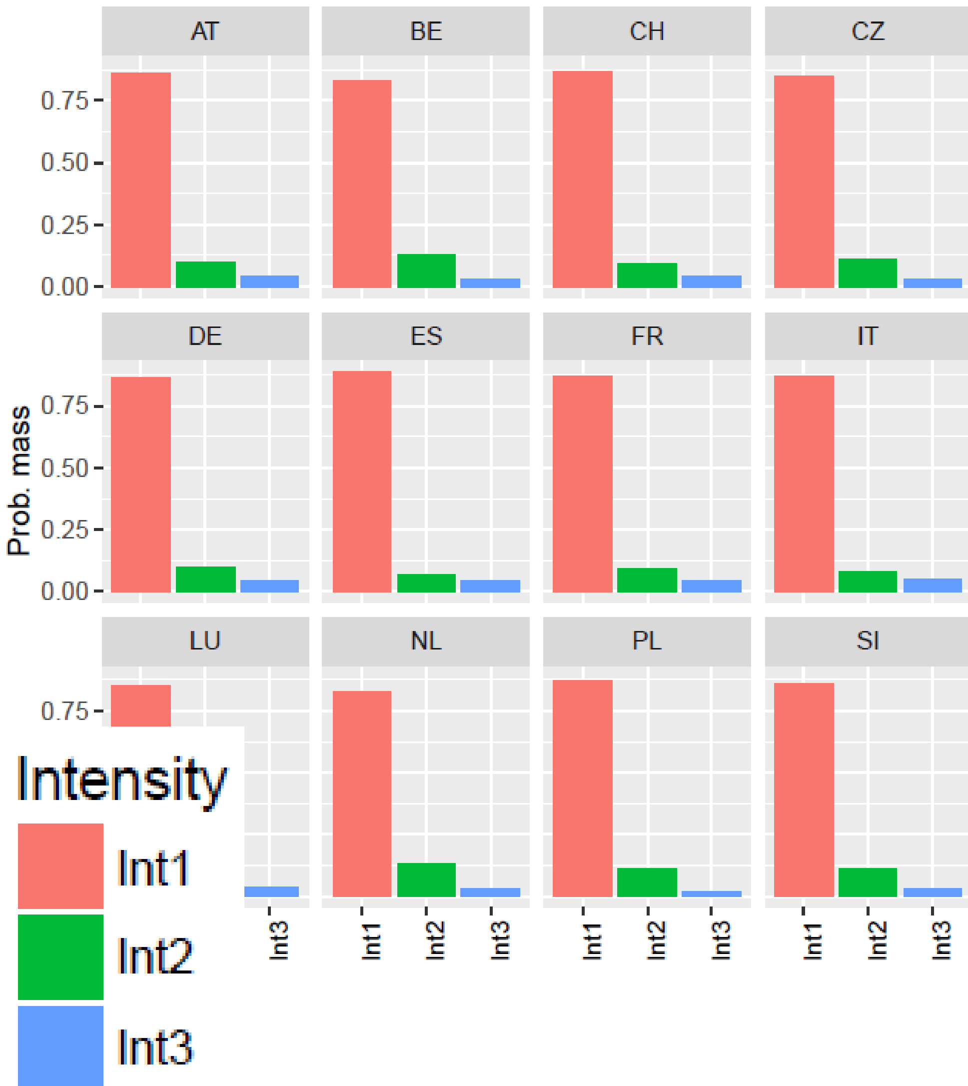


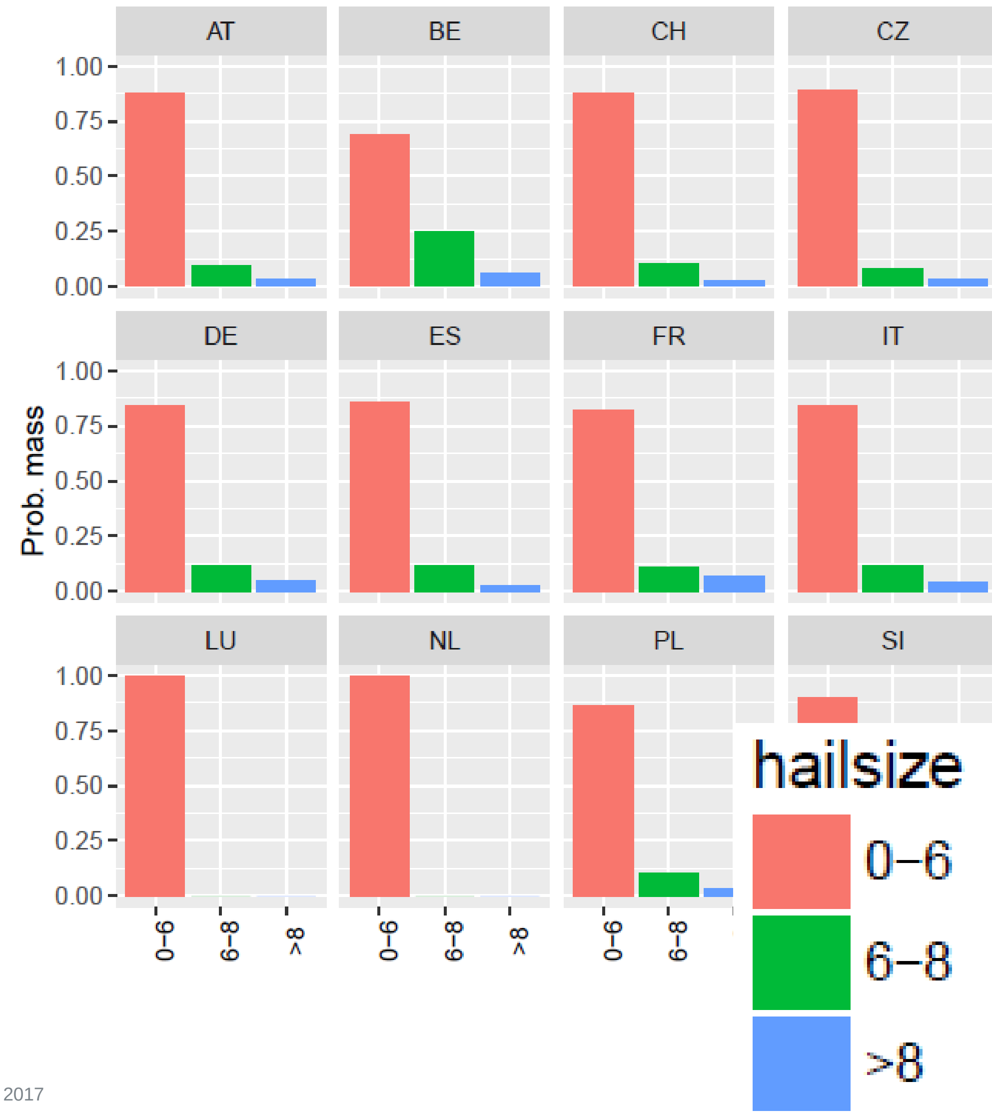
Hazard maps
By intensity

- Intensity 1 footprints: 87%
- Intensity 2 footprints: 9%
- Intensity 3 footprints: 4%



Intensity
Model vs. ESSL





Concluding remarks

- Innovative technique to derive historic **hail tracks using lightning data**.
- **Hybrid methodology** that integrates statistical models with an optimized bootstrapping technique in order to preserve the unique properties of hail tracks.
- Part of a **fully probabilistic** hail model used for insurance risk management.

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