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

S. Koumoutsaris, A. Bonazzi, M. Strasser, D. Oramas-Dorta, J. DeAguinaga, R. Cheetham

2nd European Hail Workshop
19 April 2017
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*
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.
Stochastic modelling
Simulation of Synthetic Events

Origin: historic event catalogue and hazard map
Stochastic modelling
Simulation of Synthetic Events

Identify hail storm track attributes
Identify hail storm track attributes

• Storm centre
• Bearing
• Total length
Identify hail storm track attributes

- Storm centre
- Bearing
- Total length

The ellipses are only used to define the centre point and the direction of the storm track.
Identify hail storm track attributes

- Storm centre
- Bearing
- Total length

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

- Storm centre
- Bearing
- Total length

The ellipses are only used to define the centre point and the direction of the storm track.
Stochastic modelling
Simulation of Synthetic Events

Identify hail storm track attributes

Fit a model for each attribute at each grid cell
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: \[ \exp(-\text{distance}/K) \]
- \( K \) 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:
  \[ \log L = \alpha + \beta \times \text{season} + \gamma \times \text{bearing} \]

- Take into account the influence of the neighbouring cells weighting with distance: \( \exp(-\text{distance}/K) \).
Stochastic modelling
Simulation of Synthetic Events

- Identify hail storm track attributes
- Fit a model for each attribute at each grid cell
- Simulate stochastic events
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 stochastic events using *bootstrapping*.
Bootstrapping

• For each synthetic hail storm,
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.
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
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 *bootstrapping*.

Result: stochastic catalogue and hazard map
Hazard maps
All events
Frequency by country
Hail days per year

Frequency (in hail days per year) by country

Model
Claims
ESSL
Hazard maps
Seasonal variation

Events per year
Seasonal variation
Model vs. ESSL

AT
BE
CH
CZ
DE
ES
FR
IT
LU
NL
PL
SI

Prob. mass

[Graph showing seasonal variation for different countries with NOWCAST and ESSL datasets]
Hazard maps
By intensity

- Intensity 1 footprints: 87%
- Intensity 2 footprints: 9%
- Intensity 3 footprints: 4%
Intensity Model vs. ESSL

The diagram illustrates the comparison between intensity models and ESSL for different regions (AT, BE, CH, CZ, DE, ES, FR, IT, LU, NL, PL, SI) and hail sizes (0-6, 6-8, >8). The bars represent the probability mass for each intensity level (Int1, Int2, Int3) across the specified hail sizes.
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.
The data and analysis provided by Guy Carpenter herein or in connection herewith are provided “as is”, without warranty of any kind whether express or implied. The analysis is based upon data provided by the company or obtained from external sources, the accuracy of which has not been independently verified by Guy Carpenter. Neither Guy Carpenter, its affiliates nor their officers, directors, agents, modelers, or subcontractors (collectively, “Providers”) guarantee or warrant the correctness, completeness, currentness, merchantability, or fitness for a particular purpose of such data and analysis. The data and analysis is intended to be used solely for the purpose of the company internal evaluation and the company shall not disclose the analysis to any third party, except its reinsurers, auditors, rating agencies and regulators, without Guy Carpenter’s prior written consent. In the event that the company discloses the data and analysis or any portion thereof, to any permissible third party, the company shall adopt the data and analysis as its own. In no event will any Provider be liable for loss of profits or any other indirect, special, incidental and/or consequential damage of any kind howsoever incurred or designated, arising from any use of the data and analysis provided herein or in connection herewith.

Statements or analysis concerning or incorporating tax, accounting or legal matters should be understood to be general observations or applications based solely on our experience as reinsurance brokers and risk consultants and may not be relied upon as tax, accounting or legal advice, which we are not authorized to provide. All such matters should be reviewed with the client's own qualified advisors in these areas.