MODELLING EUROPEAN HAIL RISK USING GROUND HAIL REPORTS AND WEATHER RADAR DATA FOR INSURANCE LOSS ESTIMATION

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(Dated: September 12, 2007)

I. INTRODUCTION

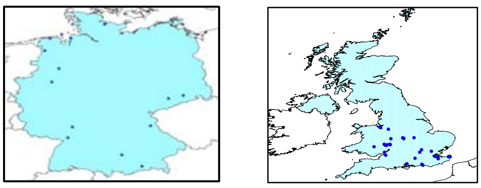
Hail can be a significant hazard in Europe especially during the summer months. Though rather infrequent compared with the contiguous US, extreme hail in Europe can cause catastrophic losses to buildings and automobiles. The spectacular Munich hailstorm in 1984 manifests the great damaging power of extreme hail (Swiss Re, 2005) and underscores the needs for insurance industry to adequately quantify the hail risk in Europe.

In this endeavour, two separate event-based hail risk models are developed for UK and the continental Europe, respectively. The hail risk model for the continental Europe currently covers Belgium, Germany, and Netherlands. The models are not only intended to price individual sites for hail coverage but also to project catastrophic hail losses for companies to manage hail risks and to assess reinsurance needs at portfolio level. Therefore a hail event is defined in this endeavour as a congregation of individual hailstorms spawned by the same convective precipitation system crossing each modelled country within 72 hours.

This paper begins by discussing the availability of historical hail data that can be used in hail risk modelling. The discussion further extends to compilation of historical hail events and the simulation of stochastic hail events. The paper mentions briefly the vulnerability functions used in loss estimation for automobiles inflicted by hailstorms.

II. HAIL DATA AND COMPILATION OF HISTORICAL HAIL EVENTS

Severe hail reports are available in Germany and UK. A hailstorm is considered to be a severe hailstorm when hailstone diameter exceeds 19 mm. The Germany severe hail reports V1.5 since 435 were made available at TorDACH website http://www.tordach.org/de/. The data quality is rather poor. UK hail reports of reasonable quality are available since 1870s through TORRO (Webb, et al., 2001). Shown in Figure 1 are two historical hail events compiled using the hail reports for Germany and UK, respectively.

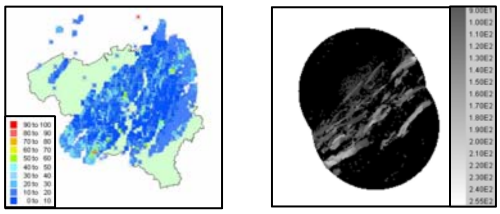


(a) (b)

FIG. 1: Historical hail event compiled for (a) Germany and (b) UK.

Such severe hail reports were nonexistent at nationwide scale in Belgium and Netherlands. Weather radar data are therefore used as alternative data that are empirically translated into virtual severe hail reports through simulation. Two-year worth of radar data were obtained from the Royal Meteorological Institute of Belgium (RMI) for Belgium (Delobbe and Holleman, 2003) and the Royal Netherlands Meteorological Institute (KNMI) for Netherlands (Holleman et al., 2000), respectively.

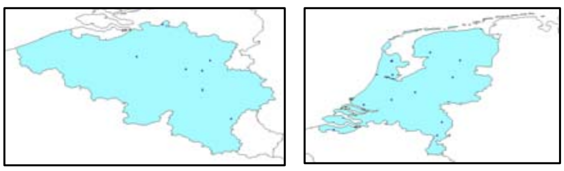
The radar data have typically a 15- minute temporal resolution and approximately 3km x3km spatial grid resolution. The radar data also provide information for each grid that can be used to estimate latitude, longitude, and Probability of Hail (POH) on the ground. Hail cells are identified using empirical criteria developed in this endeavour. Each identified hail cell is then assigned by a pair of latitude and longitude and a POH. It is believed that only severe hailstorms are likely to cause damage to buildings and automobiles (Hohl, et al, 2002). The POH is therefore further converted into Probability of Severe Hail (POSH) using the results from a study by Changnon (2001). Sample radar data are shown in Figure 2.



(a) (b)

FIG. 2: Sample radar data from (a) Belgium and (b) Netherlands.

Virtual severe hailstorm reports are simulated for Belgium and Netherlands using the identified hail cells. The latitude and longitude of a virtual hailstorm report is simulated by perturbing those of a hail cell. The perturbation function is a Gaussian distribution with standard deviation equal to 4.5 km. Selection of the perturbation standard deviation is derived based on a study by Holleman (2001). Simulated virtual severe hail events are shown in Figure 3 for Belgium and Netherlands, respectively.



(a) (b)

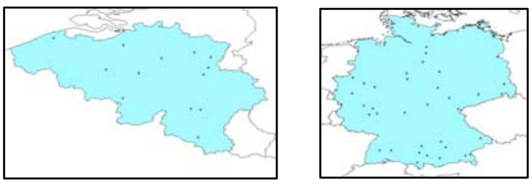
FIG. 3: Virtual severe hail events simulated for (a) Belgium and (b) Netherlands.

III. SIMULATION OF STOCHASTIC HAIL EVENTS AND HAIL IMPACT ENERGY

Monte Carlo simulation techniques are employed to simulate up to 1,000,000-year worth of future possible hail events in order to achieve stable loss estimates. The simulation process starts with simulating the probable number of hail events in a simulation year for each modelled country by sampling from their respective Poisson distribution. The seasonality of the simulated hail events are also simulated using historical seasonality information available in Germany and UK.

Different empirical approaches are developed to simulate stochastic hail events to accommodate the type and availability of hail data in modelled countries. The hail reports of reasonable quality are available in UK since 1870s. Hence simulation of a stochastic hail event in UK is accomplished by (1) selecting a historical UK hail event based on its simulated event date, (2) perturbing all hailstorms in the selected historical event together in longitude and latitude directions using a bivariate Gaussian distribution, and (3) perturbing independently individual hailstorm using a bivariate Gaussian distribution. This approach is similar to that used for US hail risk modelling by Yin et al. (2007).

To accommodate the lack of quality hail data, a different approach is developed to simulate hail events and individual hailstorm in each event in Belgium, Germany, and Netherlands. Number of hail events in a simulation year and number of hailstorms in a simulated event are first empirically derived for each modelled country using the hail reports in Germany and the simulated virtual severe hailstorms in Belgium and Netherlands. Number of hail events in a year follows Poisson distribution and number of hailstorms in an event follows exponential distribution. To find the likely location of a simulated hailstorm, hail climatology is required. Hail climatology is defined in this endeavour as the probability of hail occurrence at 0.01^0(1km) grid resolution. A unified hail climatology for Belgium, Germany, and Netherlands is achieved by smoothing the historical hail reports in Germany and virtual severe hail reports simulated for Belgium and Netherlands. The optimal standard deviation for the bivariate Gaussian smoothing function is determined using a jack-knife cross-validation techniques described in Hall and Jewson (2005). The smoothed hail occurrences by grid are then normalized by the total hail occurrences for all the grids in a modelled country and become grid probability of hail. The location of a simulated hailstorm is sampled using this hail climatology. This approach implies that the locations of simulated hailstorms are independent. Simulated hail events are shown in Figure 4.



(a) (b)

FIG. 4: Simulated hail events for (a) Belgium and (b) Germany.

Hohl et al. (2002) successfully correlates radar-derived hail impact energy with automobile hail loss claims. In this endeavour, hail impact energy that includes both gravitational and windblown components is simulated and used as hail hazard intensity to estimate automobile hail losses. The method used to calculate hail impact energy in this endeavour is based on the approach proposed by Matson and Huggins (1980). The physical parameters required for hail impact energy calculation and probability distribution functions selected to fit these parameters can be found in Yin et al. (2007).

IV. VULNERABILITY FUNCTIONS AND LOSS ESTIMATION

Innovative hail vulnerability functions for automobiles are developed in this endeavour. Three separate vulnerability functions are developed to explicitly account for the dent repair labour cost, parts replacement cost and depreciation cost, respectively. The depreciation cost is particularly applicable to manufacturer automobile coverage since an automobile can no longer sell at its original price even if it is fully repaired. These hail vulnerability functions better reflect how automobile hail loss claims are adjusted in the real world and hence provide more realistic loss estimates.

V. CONCLUDING REMARKS

In this endeavour, two separate event-based hail risk models are developed for UK and the continental Europe that currently only covers Belgium, Netherlands and Germany, respectively. Different empirical approaches are developed for hail hazard simulation to accommodate the varying degrees of hail data type, quality and availability in the modelled countries. Monte Carlo simulation techniques are employed to simulate up to 1,000,000-year worth of future possible events. Hail impact energy is simulated and used to estimate damages. Continuing improvements to the modelling approach and model results are expected as more reliable hail data and new modelling technologies emerge.

VI. REFERENCES

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