

Summary

This thesis investigates the effect of windstorm clustering over the BeNeLux. When a windstorm arrives in the European mainland, there appears to be an increased chance of another storm arriving. This weather feature has recently gained attention of catastrophe modellers and is important in the determination of capital requirements. The modelling of catastrophe risk is usually done by third parties, *vendors*, who calculate and sell the predictions for catastrophic events like windstorms. They have options to include clustering in their models, but rarely disclose their specific methods. To gain insight into this type of modelling, the process of storm formation and the definition of clustering are assessed. Based on Dutch and Belgian weather data, a model for the arrival rate of severe storms is constructed. To measure the dependence of these storms, the overdispersion of the number of storms per winter is studied. The parameters for (zero-adjusted) Poisson, Negative Binomial and Poisson-Binomial distributions are estimated from the empirical data and compared with earlier literature on the subject. Also the storm tracks of some severe clusters are investigated and used to illustrate the causes of dependent storm arrivals. The paragraphs below summarise the main findings of this thesis.

The size of the storm insurance business and the corresponding capital requirements ask for precise prediction of the expected losses. As these losses can be over 100 million euro for the rarest events, also reinsurance contracts are important to cover potential losses. The capital requirements for insurers and reinsurers can be calculated according to the standard model specifications of the European Insurance Authority. These specifications explicitly assume two consecutive storms to be independent. However, for the correct modelling, in for example an internal model, the effect of clustering should be incorporated. Catastrophe models consist usually of a hazard, an exposure, a vulnerability and a financial module. This last module exists to calculate the financial consequences of a catastrophe and is a possible place to incorporate effects of clustering through post loss amplification.

To model the dependence in the arrival of storms per winter, a list of storms is identified from wind gusts data of the Belgian and Dutch Royal weather institutes. The storms are identified using the method that is often used in other studies. A meteorological index is calculated for every day in the data. The two percent heaviest gusts per station are normalised, cubed and summed to get the index per date. Based on this list of indices, storms arriving together within seven, fourteen and thirty days are identified as clusters. On these observed distributions of storms per winter theoretical distributions are fitted.

The arrivals of successive storms can be modelled with a homogeneous Poisson process. However, when we look at the variance of the number of storms divided by the mean number of storms as a measure of overdispersion, it is clear that a different distribution with an additional parameter is more suitable. Since overdispersion is clearly present in the data, the Negative Binomial distribution is fitted. The observed storm distribution shows also an excess of zero storms compared to the fitted Poisson and Negative Binomial distribution. Therefore an additional parameter is added and the zero-inflated and zero-adjusted Poisson and Negative Binomial distributions are fitted. An alternative model that comes closer to the actual process underlying the cluster development is the Poisson-Binomial model. This model estimates the number of clusters per winter and the size of the clusters separately. The number of clusters is estimated with a homogeneous Poisson process after which the cluster size is estimated with a Binomial distribution.

The models above are evaluated using the χ^2 -test statistic and the Akaike Information Criterion. The Negative Binomial distribution shows the best fit, followed by the zero-inflated and adjusted models that are a clear improvement over the Poisson model. When defining clusters as storms arriving within seven or fourteen days the Poisson-Binomial distribution fits well. However, when increasing the time frame to thirty days the predictive power diminishes. This makes sense since less information about the inter-arrival times of storms is used. Under the assumption that favourable storm development conditions last longer than two weeks, a Negative Binomial distribution is more suitable. Based on the Poisson-Binomial model a simple pricing example is given to calculate the effect of clustering on insurance premiums. This application relies on strong assumptions and should not be overvalued but gives an easily implemented method that shows the impact of clustering. As an alternative to the statistical modelling of clusters, the possibility to incorporate clustering in the post loss amplification is also discussed. This alternative approach overcomes problems that arise for example at Lloyd's of London, one of the world's largest insurance markets. When different vendor models are used within one company it is impossible to combine the probabilities of losses in a statistically correct manner. By increasing the size of the losses at the end of the modelling, clustering can be accounted for.

The models above are also fitted on the list of storms derived from the ERA-Interim data set of the European Centre for Medium-Range Weather Forecast. This data also illustrates the dependent arrivals of storms. Comparison of the estimated parameters with other literature shows that the area and time period of interest are very important when investigating clustering. Dispersion factors are estimated with large confidence intervals and depend also on the intensity of storms and the position of the storm track over the Atlantic Ocean.

Obviously insurers are mostly interested in the number of storms that are actually arriving over the BeNeLux. Nevertheless it is important to understand the underlying processes of dependent development of storms when modelling the losses. The storms arriving within short time intervals do not necessarily have the same origin. To describe the clustered arrival, a distinction is made between secondary cyclogenesis, clustering due to large scale pressure variations, and storms that appear to arrive independently. To investigate nine periods of severe storms in the last twenty-five years and the different ways clusters develop, a simple JavaScript application is written. The visualisation is a powerful tool to compare the tracks and developments of storms in time. In two of those nine periods the first storm seems to initiate a second storm. In four periods the storms develop separately but are steered to the European coast by large scale pressure patterns. In two periods the storms arrive together but develop and travel independently over the ocean. A period consisting of four big storms shows all of the three effects above and is a good example of the complexity of the processes underlying cluster development. The challenge will remain to model the storm arrivals as simply as possible while considering all factors that play a role and are relevant for insurers.

Schematic overview