Flood Research Needs of the (Re)insurance sector

Collaborating to improve risk understanding and management
Lighthill Risk Network
in collaboration with Flood Re

Flood Re is a joint initiative between the U.K. Government and insurers. Its aim is to make the flood cover part of household insurance policies more affordable and is planned to be in place until 2039 after which there will be a free market for flood risk insurance. Therefore, Flood Re also has a role to help manage a transition to home insurance prices that fully reflect flood risk. This means that people benefiting from Flood Re need to become more aware of their flood risk and, if possible, take action to reduce it. At the same time, flood losses are rising, in part due to socio-economic trends such as urbanisation, more buildings in exposed areas, and failed land-use practices, and climate change is expected to exacerbate these risks in some areas.

Significant R&D has been invested into catastrophe flood risk models in the last several years leveraging rapid advances in computing power. However, flood risk is a particularly challenging peril to model, and the risk is changing. Many significant uncertainties remain which would benefit from input from the academic and earth observation communities.

One of the roles of the Lighthill Risk Network is to improve the linkages between academia and the (Re)Insurance Industry. Flood Re and the Lighthill Risk Network collaborated in 2018 to identify key areas of industry needs on Flood Risk Modelling. The goal was to create a prioritised list of problems and questions that the insurance industry has on flood risk modelling to feed into academic priorities and upcoming funding calls from e.g. NERC and potentially the LRN itself. This research may either help improve flood model methodologies and development, support end-user validation of flood models, or help improve accuracy of results through improved input data.

The initiative started by soliciting industry input from several UK and European insurers and (re)insurers with significant flood (re)insurance exposure. Each of these was topics was subsequently weighted in importance by each (re)insurance entity and averaged across all participants. The companies who contributed to the initial weighting of priorities are Flood Re, Willis Re, Guy Carpenter, Direct Line, Lloyds TSB, Aspen, Allianz, SCOR, Swiss Re.

The results from the exercise are being distributed to others for further input via this report, a seminar in 2019 bringing together industry, academic and earth observation communities, and other relevant initiatives such as the 4th Flood Club workshop meeting held at Willis Towers Watson in January 2019 and the Oasis London conference in June 2019.
Table 1  
Ranked List of Flood Model Topics in order of Importance

<table>
<thead>
<tr>
<th>Model Topic</th>
<th>Problem</th>
<th>Industry Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerability curves</td>
<td>Use of mean damage ratios is computationally efficient, but oversimplifies the reality of damage distributions, potentially creating bias.</td>
<td>13%</td>
</tr>
<tr>
<td>Hazard</td>
<td>Correlation of rainfall/flood and windstorm - assess the contribution of flood losses to wind events and vice versa.</td>
<td>8%</td>
</tr>
<tr>
<td>Vulnerability curves</td>
<td>Use of flood depth as the hazard metric is standard in flood catastrophe risk models – however, claims data suggests duration and/or velocity might be more predictive of damage.</td>
<td>7%</td>
</tr>
<tr>
<td>Digital Terrain Data</td>
<td>Current global DTM are relatively old, not up to date, and too low-resolution for detailed flood risk modelling.</td>
<td>7%</td>
</tr>
<tr>
<td>Flood defence database</td>
<td>One of the main determinants of flood risk, and a key source of uncertainty in risk modelling is the location of flood defences, their standard of protection, and their quality.</td>
<td>7%</td>
</tr>
<tr>
<td>Climate change</td>
<td>To what degree are climate change signals baked in to today’s catastrophe model, e.g. via the historical rainfall data used.</td>
<td>6%</td>
</tr>
<tr>
<td>Pluvial flood modelling</td>
<td>The ratio of losses from pluvial to fluvial flooding has been observed to vary considerably between catastrophe risk models along the EP curve.</td>
<td>6%</td>
</tr>
<tr>
<td>Hazard - tail events</td>
<td>There is concern that flood catastrophe models generally under-sample events in the tail, e.g. there are not many breaches of defences at the 1 in 200 level purely as a function of the lack of enough events in the tail of the event set.</td>
<td>5%</td>
</tr>
<tr>
<td>Off-floodplain claims</td>
<td>It is often observed by insurers that flood claims occur away from the floodplains, even in very strongly fluvial flood events. Need to understand in more detail the differences between properties which have claims and those that don’t.</td>
<td>5%</td>
</tr>
<tr>
<td>Hazard - tail events</td>
<td>Are tail event footprints realistic in terms of their spatial extent and severity/flood depths?</td>
<td>4%</td>
</tr>
<tr>
<td>Urban drainage network design</td>
<td>Catastrophe models often have to apply a broad-brush “standard of protection” approach to urban drainage, and many simplifications are needed due to the high computational requirements of detailed urban flood modelling. What would the impacts on loss results be of improved modelling?</td>
<td>4%</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>What are the really important characteristics of properties which influence losses. What credits should be given on pricing for specific resilience features?</td>
<td>4%</td>
</tr>
</tbody>
</table>
### Model Topic | Problem | Industry Weighting
--- | --- | ---
Super-catastrophe events | What is the impact of damage and disruption of very large flood events to critical infrastructure on recovery times and the subsequent impact on insured losses such as business interruption, ALE etc. | 4% |
Pluvial flood modelling | Are there better ways to model pluvial flooding than current approaches, e.g. incorporating detailed terrain modelling of where water flows to, antecedent conditions, etc. | 3% |
Model validation - historical events | Historical event footprints do not match modelled historical footprints because of changes/impacts of new flood defences, so it’s hard to validate catastrophe model using historical footprint data. | 3% |
Hazard modelling - flood gauge data sensitivity testing | Gauge station flow data are limited. We have seen in recent events e.g. Carlisle very long RP flows. Were they really that extreme or is it a function of the limited historical data? | 3% |
Exposure | Problems continue with the transfer of exposure data details. Can AI/machine learning and Earth Observation data be used to build an exposure database. | 2% |
Hazard modelling validation - rainfall vs gauge data approaches | Rainfall-runoff versus gauge data approaches for flood modelling can provide very different results. Model comparison of the two would help users assess each approach and their differences. | 2% |
Flood defences | Modelling of flood defence failures too coarse and doesn’t reflect reality | 2% |
Super-catastrophe events | Is there any correlation of catastrophe flood events with other events/economic failure - Could a big enough flood event impact the stock market? | 0.5% |

One particular observation that can be made is how similarly weighted many of the topics are, reflecting the broad range of issues that remain for flood risk modelling and understanding.

Some topics will not be able to be addressed by the research community, either due to lack of available data or because they are not a research topic per se. However, this exercise has also served as a user-community feedback mechanism to the developers of flood catastrophe models and should stimulate groundwork for future improvements, for example on data collection. Some problems may only be solved by the industry itself, for example the sharing of detailed claims data which is becoming an increasingly sensitive issue given the need to respect data privacy rights.

The following section of the report gives more detail about each of the identified problems during the discussion and some of the suggested research and collaboration avenues to explore. This is not exhaustive and requires more interaction between industry, academia and the earth observation community to find aligned research objectives and possible solutions.
01. Vulnerability curves – use of mean damage ratios

Traditionally, catastrophe model vulnerability curves have been based on a calculation of mean damage ratios (cost of repair as a percentage of the replacement value/sum insured) as a function of hazard intensity, with an uncertainty distribution. This is a very computationally efficient process but oversimplifies the reality of damage distributions – particularly for flood, where the damage is driven by multiple factors, and damage ratios do not scale linearly with property values. In addition, there is often a significant difference between rebuild cost inflation which affects the catastrophe model numbers and claims inflation which firms actually pay, contributing to why model MDRs don’t capture actual losses well.

As the models are typically reviewed infrequently using data from the last big event, this difference can mount. Other statistical approaches to deriving vulnerability, for example parametric models and in particular the Generalized Linear Model (GLMs) have been found to be advantageous in a study on Tsunami vulnerability modelling (Macabuag et al 2018). Developing such an approach requires the collection and analysis of very detailed data following flood events to identify which buildings have been affected by which type of flood (high velocity, vs low velocity, long duration, etc) via physical surveys, and relate to building by building claims data. Research into appropriate methods for flood would be beneficial before implementing into commercial catastrophe models.

02. Hazard – correlation of rainfall/flood and windstorm

Recent events in particularly in the U.K. in the last few years have highlighted the issue of correlation between wind and rainfall within events, and this topic is highly-ranked in windstorm research priorities. Some work has been done e.g. by the Willis Research Network, but there is a need to understand the potential for this more, and its impact through the EP curve.

One suggestion from the industry group is to create an open-source historical database with the split between the different loss causes for historic events. Another suggestion is the possible use of physical weather models to simulate longer time periods and examine the correlations, although it was noted by the industry group that this could be highly resource intensive.
03. Vulnerability curves - use of flood depth as the hazard metric

As indicated in the first vulnerability topic above, the use of flood depth is standard in flood catastrophe risk models as the driver of vulnerability. However, claims data shows significant uncertainty, and it is suggested that duration and/or velocity also have an influence on losses as well as how much warning is given before an event allowing occupiers to take action. Therefore, different types of flood have quite different loss ratios.

The lack of available claims data for researchers to be able to develop new vulnerability curves for different building types in different regions is a challenge for improving vulnerability modelling. One possible solution is for researchers to go in-house into partner insurers to study their claims data thus reducing data protection concerns. Another approach is to look at other available data sets, such as empirical flood loss data on direct damage to residential buildings available from computer aided telephone interviews that have been compiled after major floods in Germany. GFZ Potsdam is using this data to develop and compare new complex flood damage models (e.g. Schröter et al, 2014). Can this approach to collecting more data be replicated in the U.K. following future floods, and who would own and run this process?

04. Open-access digital terrain data

Current global DTMs are relatively old and do not reflect recent land-use changes. In addition they are too low-resolution (e.g. 90m) for detailed flood risk modelling, which has to be done with expensive commercial high-resolution data. Can the Earth Observation community produce improved data on an open-access basis? What projects have already been attempted on this, have they been successful and if not why not?
05. Flood defences - database of flood defences + standards of protection

One of the major determinants of flood risk, and source of uncertainty in flood risk modelling, is the location and standard of protection of flood defences. There is a lack of consistent information across countries, and sometimes the information is not available at all. Even if a database of flood defences is available, the standard of protection is not always known, let alone the maintenance/upkeep of the defence and its probability of failure.

A database of existing defences with metrics to help assess the probability of failure would be a valuable tool for the industry as well as property owners. This needs to be developed in conjunction with government/public science/space agencies.

06. Climate change impact on current risk levels

The question was asked by re/insurers to what degree are climate change signals baked in to today’s cat models via the historical rainfall data used to develop and calibrate the model. In addition, users are asking what historical period of time is appropriate for to reflect the current risk? There is demand for an improved understanding of the impact of climate change on frequency and severity of flood losses for different time periods and different countries.

Several extreme event attribution studies have shown that anthropogenic climate change has increased flood risk in the U.K. and Europe, e.g. Yiou et al., (2013) suggests “a contribution of climate change to precipitation rate in northern Europe. We conjecture that such a trend could be due to precipitation rates within the cyclonic patterns, which convey more moisture because of increased temperatures”; Pall et al., (2011) found that “In nine out of ten cases our model results indicate that twentieth-century anthropogenic greenhouse gas emissions increased the risk of floods occurring in England and Wales in autumn 2000 by more than 20%, and in two out of three cases by more than 90%”, and “climate change making precipitation events like [storm Desmond on 4–6 December 2015] about 40% more likely” (Otto et al., 2018). Can the results from these attribution studies be used to adjust catastrophe model frequency/severity distributions? What other scientific advancements can be used to answer these questions?
Additionally, is there evidence of a flood rich and flood poor periods, as suggested previously by research by UK Met Office and analysis by Willis Towers Watson https://blog.willis.com/2016/12/u-k-floods-should-we-expect-more-of-the-same/?

There is interest in understanding how much the risk has already changed from the long-term historical average. Potsdam Institute for Climate Impact Research (PIK) are developing a “current climate” view of risk for the Danube river flood risk model as part of the Oasis+ H2020 Insurance project, which will reflect the time period 2000 - 2020, in addition to a historical view (1970-1999) and future climate 2020-2049 view. The flood modelling company JBA has released a new UK climate-change flood model based on long-term future climate modelling to 2040 (https://www.jbarisk.com/news-blogs/new-uk-climate-change-flood-model/) although it was acknowledged by the industry group that more discussion on how this is used in the business is needed and how uncertainty is being reflected.

07. Ratio of pluvial to fluvial flood losses

The ratio of losses from pluvial (off floodplain) to fluvial (floodplain) flooding varies considerably between available catastrophe risk models along the EP curve, and there is concern that some models overstate this at longer return periods. The variation is probably a result of different modelling approaches being used for the pluvial component in particular.

An independent quantification of the contribution of pluvial flood to overall flood losses for historical floods for different countries would be beneficial to help users validate this aspect of catastrophe models.

Another approach could be for an academically-driven model comparison of the ratio of pluvial to fluvial losses along the EP curve (annual losses from an unusually wet season) vs. OEP flood occurrences that occur within a restricted period of time for different types of methodology.
08. Hazard - tail events

There is concern that flood catastrophe models generally under-sample events in the tail, e.g. there are not many breaches of defences at the 1 in 200 level purely as a function of the lack of enough events in the tail of the event set. However, catastrophe models should not overstate the probability of very severe tail events, as this has a big impact on 250-year loss assessment.

Independent model comparison exercises focused on tail-distributions of events produced by different model methodologies may help shed some light on this problem. This could be done using open-source academic models and publishing the results for end-users to compare with their catastrophe model of choice. Alternatively, this could be a focus for future industry catastrophe-model comparison panels, or by an independent academic comparison of catastrophe models – though both would rely on commercial catastrophe model companies agreeing to participate.

09. Drivers of off-floodplain claims

It has often been observed by insurers that flood claims occur away from the floodplains, even in very significantly fluvial flood events. This may be due to a combination of localised sources of flooding such as surface flooding, ground-water flooding, and/or and property characteristics. It can impact properties that are not identified as at risk on Environment Agency flood maps or in catastrophe models. Surface water flooding in very heavy rainfall events is likely on the increase due to climate change (see link to climate change topic). There is a need to understand in more detail the differences between properties which have claims and those that don’t, which will help modellers improve their risk models, as well as ultimately for homeowners to be able to take steps to mitigate their risk. This again raises the issues around availability of detailed flood claims data for researchers, as per the previous topic on vulnerability curves – drivers of damage, and the need for innovative approaches to gathering data following events which can be used for research.
10. Hazard - are tail event footprints realistic

Current modelling techniques rely on extrapolating from low river discharge RPs to high river discharge RPs for extreme events. Define criteria to validate whether the extreme event footprints found in catastrophe models are physically realistic and possible, potentially using the output of climate models. For flood, the most extreme loss events are thought to be those which are very widespread and impact multiple river basins at the same time. One question is how frequent are these types of events compared to smaller but very intense events, and linked to the climate change question, is the frequency of these types of events changing. Independent research to help validate the nature and size of extreme events would be useful, looking at differences between UK and Europe, and considering small and large portfolios.

11. Urban drainage network modelling

Catastrophe model typically have to apply a “standard of protection” approach to urban drainage, and many simplifications are needed due to the high computational requirements of detailed urban flood modelling using hydrodynamic approaches for entire event sets.

However, computationally efficient detailed urban flood models are emerging. For example, Denmark invested significantly following the Copenhagen 2011 Cloud Burst, and the Danish Technical University of Copenhagen has developed an urban pluvial flood model for rapidly estimating flood extent, depth and its associated damage. Following positive comparisons to hydrodynamic models, it is being applied to cities along the Danube, as part of the Oasis+ H2020 Insurance Future Danube project which will output an Oasis ready Danube flood model.


More published studies of the flood risk of key cities using these emerging models would help catastrophe model end-users validate their catastrophe model. Ultimately these models could be integrated or meshed into commercial catastrophe model for key cities.
12. Vulnerability - which are the most important property characteristics that influence losses

Quantify the impact of exposure attributes on flood losses to improve modelling, help determine incentives for homeowners and communities to invest in resilience and resistance features where feasible through resilience credits. Flood Re have sponsored research by the University of the West of England into the effectiveness of property flood resilience (PFR) and its financial viability, including both post-flood repair and proactive resilience intervention. The report concludes that PFR measures are beneficial and play an important role in flood risk management, whilst acknowledging that further research is needed to quantify the merits of PFR (Flood Re, 2018).

13. Super-catastrophe events – damage to critical infrastructure and long-term recovery times

What is the impact of damage and disruption of very large flood events to critical infrastructure on recovery times and the subsequent impact on insurance losses such as business interruption, Alternative Living Expenses, etc.? Understanding the dynamics of demand surge and pressure on housing after an extreme season of flooding country-wide would be useful, for example through detailed scenarios or historical analysis.

The Environment Agency has calculated the economic impacts of historical UK floods (e.g. the 2015/16 winter storms https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/672087/Estimating_the_economic_costs_of_the_winter_floods_2015_to_2016.pdf), and insured losses were reported by the Association for British Insurers. However, more severe tail-event scenarios are needed to understand the impacts of very severe flooding on infrastructure and long-term impacts on economic and insured losses. Starting with severe scenarios used for National Resilience planning and assessment of critical infrastructure could be a good starting point.
14. Improved pluvial flood modelling

Given the complexities of pluvial flooding, are there improvements possible which incorporate detailed terrain modelling of surface water flows, antecedent conditions, soil types, small streams etc. What key improvements are needed to current approaches, and can academia play a role in creating new, computationally efficient high-resolution approaches which can be deployed in catastrophe models, either statistically or physically based.

15. Model validation - historical events

Historical event footprints such as from historical surveys or satellite data do not match modelled simulations produced using catastrophe models, because of the impacts of changes in flood defences which are incorporated in the up to date catastrophe models. Both the flood extent and flood depths would be different if that exact event happened today compared to at the time. Many catastrophe models do not even include historical event reconstructions, in a large part due to this reason. It is therefore very challenging for users to validate the model using historical event footprint information, which in itself is very limited. Independent “as if” historical reconstructions (as if they happened now) would be useful to support model validation. Other possible solutions are welcomed.

16. Hazard modelling - flood gauge data sensitivity testing

Historical gauge station flow data are limited. Very long return period flows have been recorded in recent events, e.g. Carlisle in 2005. Were they really that extreme or is it a function of the limited historical data? What is the reliability of extreme value data? What is the impact on the return period of extreme event scenarios by adding more extreme events into the historical data?
17. Detailed exposure data


18. Hazard modelling validation – rainfall vs gauge data approaches

Rainfall-runoff versus gauge data approaches for flood modelling can provide very different results. More comparisons of the two would help users assess each approach and their differences. For example, what kinds of model values are obtained for gauge flows from models based on rainfall-runoff modelling compared to actual gauge data for validation. Another issue is the application of rainfall-runoff models to non-gauged catchments. Different models are calibrated in different ways, and as a result can produce very different results in non-gauged catchments. The model comparison could be done using published open-source academic models, or using commercial cat models if the developers agree to this. Many end-users do not have access to more than one cat model, given the expense of licensing and running them.
19. Detailed modelling of flood defence failures

Modelling of flood defence failures is typically too coarse and doesn’t reflect reality, resulting in over-stated model footprints. In reality small breaks occur in flood defences which release pressure downstream, or there is a breach on one side of the river bank only. What improvements in flood modelling computational efficiency can be made to improve the resolution of flood defence modelling?

20. Super-catastrophe events and stock markets

Is there any correlation between catastrophic flooding, particularly those covered by ILS and other economic failure events? Could catastrophic flooding in the UK or Europe be severe enough to have a significant impact on stock markets? Could this impact other stock markets in other regions? Contagion effects between stock markets globally have been documented during historical financial crises, where a country transmits market changes to other countries after a major event, given the dependency between country economies.

Many researchers have studied the contagion effects of financial crises, but few have studied the impact of natural disasters. The Osaka-Kobe Japan earthquake of 1995 and the 2008 Sichuan earthquake have both been shown to have contagion effects (Lee & Wu, 2009, and Lee et. al 2018). It is possible that no recent U.K. or European flood event has been severe enough to have such an impact, thus scenarios from catastrophe models could be used for such an economic analysis.
References
Flood Re, 2018; incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures. Available from https://www.floodre.co.uk/wp-content/uploads/Flood-Re_Position-on-Incentives_SMF-report.pdf


The Lighthill Risk Network, now incorporating the Insurance Intellectual Capital Initiative, IICI, is an all-encompassing and inclusive organisation with the specific aim of facilitating and enhancing knowledge transfer into business from academic, government and commercial experts at the forefront of risk-related research.

It is a cost effective not-for-profit organisation that is funded by industry and is managed by a core team of professionals from the (re)insurance, industry. By utilising the expertise from each sector, the Lighthill Risk Network is in a unique position of being able to link its extensive academic knowledge to the research needs of industry.

By promoting personal contacts, the network provides the business community with a gateway into the latest knowledge and understanding of risk, while at the same time presenting the scientific community with opportunities to interact with industry. Targeting the latest developments in key areas of risk, and promoting the translation of knowledge between stakeholder communities, the Lighthill Risk Network exists to focus and facilitate business’ response to risk management.

The Network aims to facilitate innovation and thus success in science, in the financial services industry and in society as a whole by creating a dynamic network of contacts linking research to risk bearers and risk managers worldwide.

Flood Re exists to promote the affordability and availability of flood insurance for homeowners across the UK. Flood Re’s operation promotes a competitive insurance market that customers can take advantage of. Flood Re does not set consumer prices – this remains a decision for insurers to make. Insurers can place the flood risk element of domestic property insurance with Flood Re at a premium linked to property Council Tax bands. Flood Re sits in the background, with the purchase of the policy and the process of making a claim being unchanged.