AXA probabilistic Severe Convective Storm model in western Europe.

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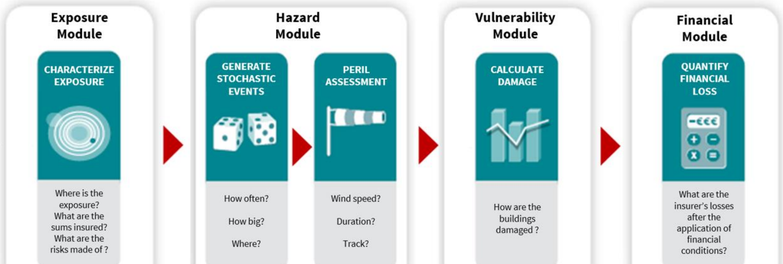
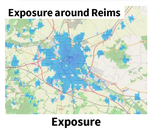
Summary

Severe convective storms are a common occurrence during spring and summer season in European countries. The damages caused by hail and wind gusts can be substantial to properties, especially on motor. The development of a convective storms hazard stochastic catalogue is an important step for AXA to assess and mitigate this peril.

We propose a method to build a catalogue of synthetic events based on multiple meteorological drivers from ECMWF-ERA5 and EUMETSAT-CMSAF. New atmospheric temporal sequences are created by reshuffling historical data, with constraints to keep physical consistency (identification of weather patterns and historical transition probabilities between them). The probability of hail occurrences is then assessed for each meteorological configuration, learning from in-situ reports (ESWD and Keraunos), with historical validation to ensure accuracy of the hail prediction. A catalog of new plausible scenarios for convective storm hazard is produced and crossed with exposure and vulnerability data to assess the subsequent risk.

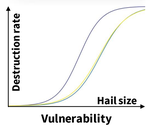
Catastrophe modelling framework




Exposure around Reims

Exposure

Hail footprint catalogue



Vulnerability

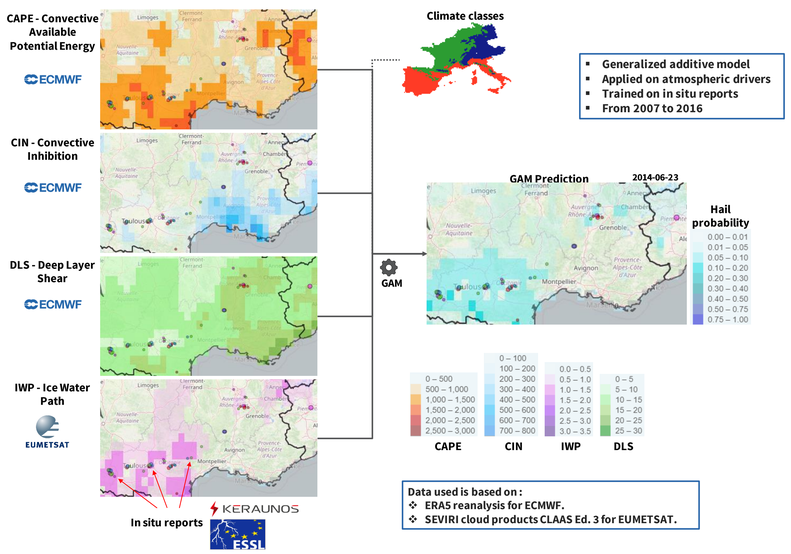
Year	Event Id	Loss
1	# 0005	27 462 948
1	# 0018	2 784
1	# 0026	35 890
2	# 0022	251 479
2	# 0031	4 839
4	# 0036	443 191
5	# 1043	98 966
5	# 0047	19 743
5	# 0049	1 614
5	# 0059	723 331
8	# 0018	3 202
12	# 0061	4 048 000
12	# 0069	41 385
13	# 0026	28 712
13	# 0075	12 008 297
		...

Data and methods

A. Hazard Module : Hail occurrence.

The formation of thunderstorms and the occurrence of hail within it is a complex process involving multiple parameters at small-scale level. A moist layer and convective energy coupled with orographic lifting or wind shear are base ingredients for a thunderstorm. Presence of condensation nuclei, updraft winds, high liquid water content and part of the cloud layer below freezing is required for hail to occur.

Unlike wind or rain, there is no atmospheric variable from weather models providing a precise assessment of hail presence and intensity, but some provide relevant hints on the hail potential for a given atmospheric configuration. Considering these variables and crossing it with in situ hail reports records, hail potential can be quantified.



- Generalized additive model
- Applied on atmospheric drivers
- Trained on in situ reports
- From 2007 to 2016

Data used is based on :
- ERA5 reanalysis for ECMWF.
- SEVIRI cloud products CLAAS Ed. 3 for EUMETSAT.

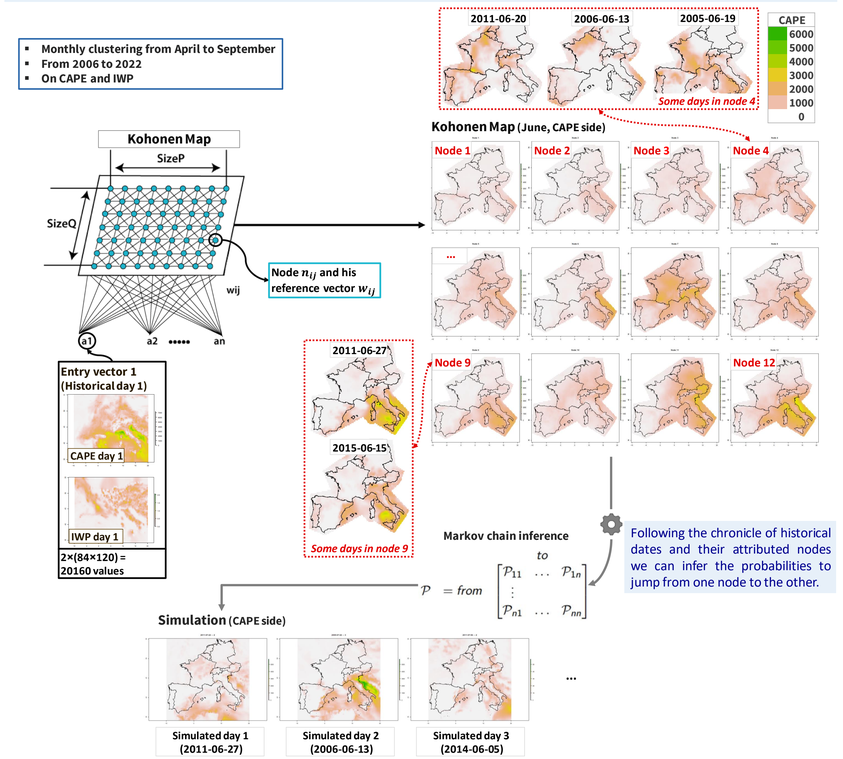
B. Hazard Module : Building meteorological scenarios.

The production of yearly hail scenarios requires physically consistent daily sequences of atmospheric drivers, on which hail will be afterward simulated using the occurrence model.

The production of atmospheric scenarios follows a two-step approach. First, a Kohonen map clustering is applied on historical data to classify days with similar weather profiles. Second, a Markov chain model is inferred on the cluster grid. Daily sequences are then produced by simulating scenarios through the Markov chain.

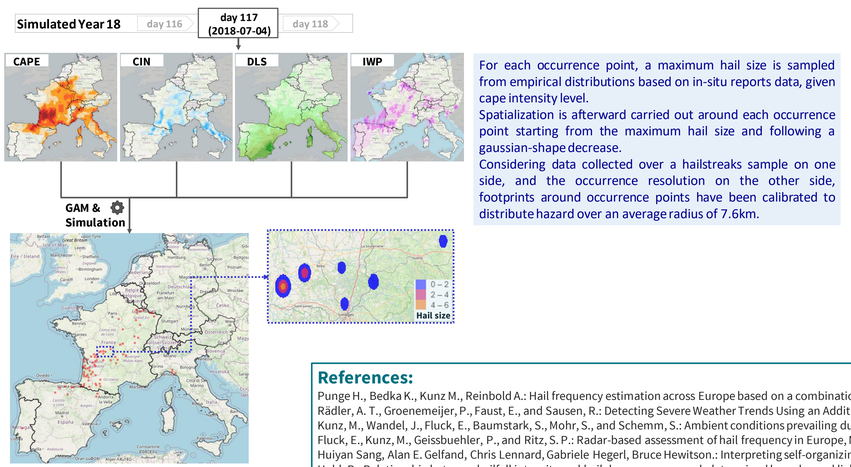
The Kohonen map classifier is applied on historical days from April to September over the 2006-2022 period. To capture seasonality effects, the clustering is performed by month.

The weather variables considered for clustering are CAPE and IWP. Unlike CAPE, IWP source is obtained through remote sensing and there might be missing data over part of Europe on some days. To mitigate this issue, a combination of short-range and long-range inverse weighted interpolations is applied to complete daily IWP.



C. Hazard Module : Simulation and spatialization.

Following a scenario of daily atmospheric sequence generated with the scenarisation submodule methodology, hail occurrences are simulated from the probabilities obtained using the GAM defined in the first submodule, a daily sequence of hail occurrence is therefore produced.



For each occurrence point, a maximum hail size is sampled from empirical distributions based on in-situ reports data, given cape intensity level.

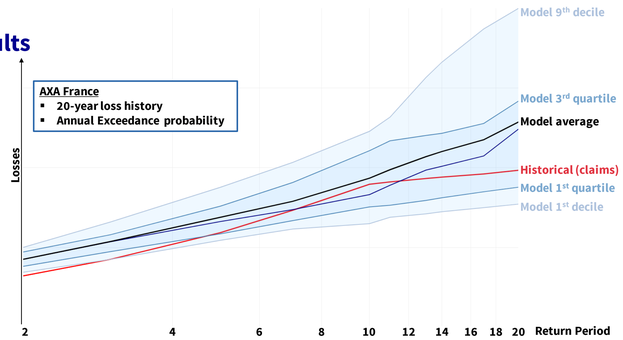
Spatialization is afterward carried out around each occurrence point starting from the maximum hail size and following a gaussian-shape decrease.

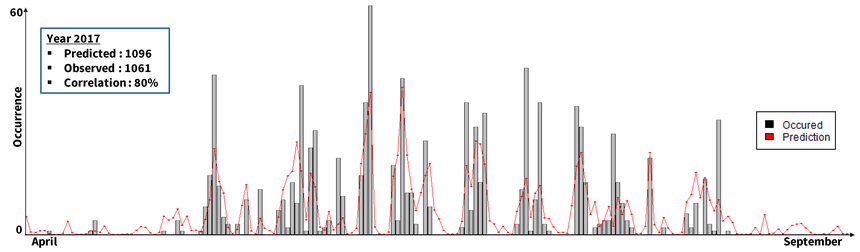
Considering data collected over a hailstreaks sample on one side, and the occurrence resolution on the other side, footprints around occurrence points have been calibrated to distribute hazard over an average radius of 7.6km.

Validation and Results

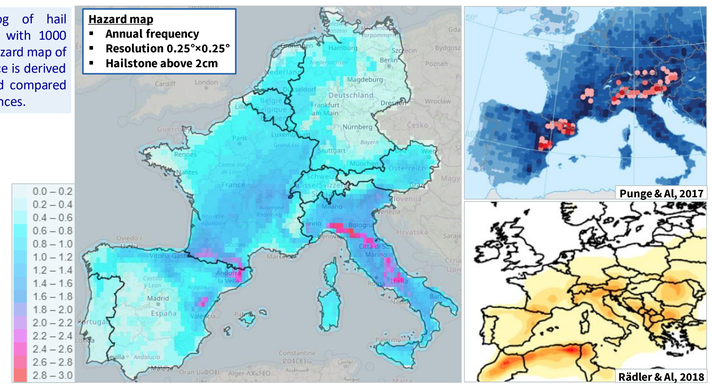
The occurrence model performance is evaluated over year 2017, on a temporal and geographical basis. The validation analysis conducted leads us to consider the calibrated GAM suitable for hail occurrence prediction.

Using vulnerability curves calibrated with AXA France claims on a dozen of large events (not shown), modelled losses are confronted with historical ones over an history of 20 years. Modelled losses over the different return periods are consistent with historical ones.





A stochastic catalog of hail events is simulated, with 1000 yearly scenarios. A hazard map of annual hail occurrence is derived from the catalog and compared with academic references.



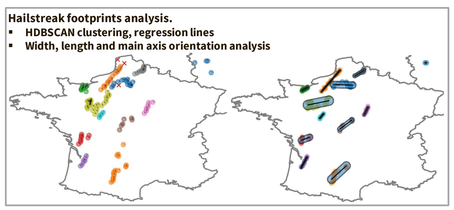
Next steps

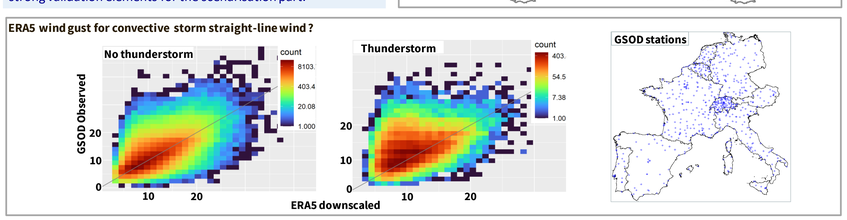
Several elements of the model can be refined to further improve the hazard and risk assessment.

The inclusion of straight-line wind hazard is currently in development.

The refinement of spatialization is also explored to obtain footprints in shapes closer to observed hailstreaks, using both statistical clustering approach on reports, literature results and a sample of radar data.

Finally, a project is underway to conduct sensitivities and define strong validation elements for the scenarisation part.





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