The contribution of climate change to Europe's increasing hail losses

Losses from hailstorms are increasingly affecting the re/insurance industry, with exceptionally high losses from the hail peril in France in 2022 and Italy in 2023. Our analysis shows that higher losses have been mostly driven by exposure and increases in claims severity. However, new scientific studies indicate that climate change may be driving modifications in atmospheric conditions, leading to more frequent large hail events.

Using our newly developed hail model for Europe, we explore how the increase in hail events could impact insured losses and discuss the consequences for the re/insurance industry.

Hail losses in Europe have traditionally been seen as a non-modelled, secondary peril from a reinsurance perspective. However, in recent years hail losses have strongly affected the re/insurance industry. Risk from hail is increasing year-on-year due to changes in exposure (such as the increasing volume of building stock) and economic factors, such as inflation of building materials and labor of approximately 3%-4% per year[1].

But how does climate change contribute to increasing hail losses? This study attempts to isolate and quantify its contribution using our proprietary probabilistic hail loss model and utilizes our scientific expertise together with atmospheric data and the latest scientific findings from the European Severe Storms Laboratory (ESSL)[2].

1 The German building cost index has increased on average of 3%-4% per year over the past 20 years (including the recent high inflation years), https://www-genesis.destatis.de/genesis//online?operation=table&code=61261-0001&bypass=true&levelindex=0&levelid=1718358034590; eigene Berechnung.
2 www.essl.org

Basis: A trend in the scientific dataset of hail probability

A growing body of scientific literature suggests hail risk in Europe is increasing due to more frequent large hail events and larger hailstones[3]. The ESSL has derived daily probabilities for large hail from 1950 to 2022 from the ERA5 reanalysis product[4]. Their analysis shows significant increases in daily large-hail probabilities in many European regions, especially in Northern Italy and Southern France (Figure 1)[5]. The ESSL analysis also shows that the relative increase of very large hail (>5cm) is higher than the relative increase of large hail (>2cm), suggesting that large hail events are not only becoming more frequent, but the hailstones are also becoming larger in size. These increases in large hail frequency and hailstone size have been attributed to climate change[5].

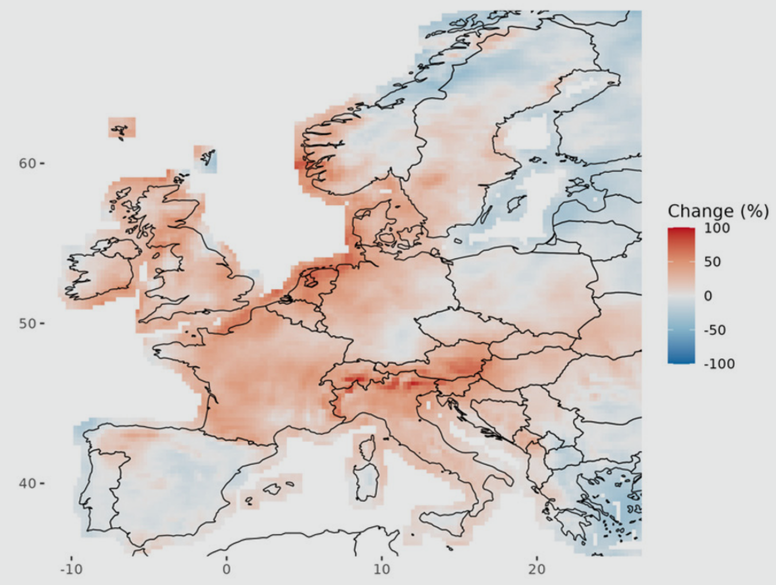

Figure 1: Relative change in hail probabilities from 1950-1980 to 1990-2020.
Relative change of probability for hail > 2 cm from the period of 1950-1980 to the period of 1990-2020 (%) in the AR-ChaMo dataset of the ESSL[6].

What causes larger hailstones?

Hailstones form and grow in thunderstorms above the altitude of the 0°C-melting level. Once they become too heavy to be carried by the thunderstorm's updrafts, hailstones fall through the underlying warmer layer of air, where they melt before hitting the ground.

As air becomes warmer with climate change, it can hold more water vapor. When the higher amount of water vapor condenses, the thunderstorm and its updraft become stronger, and hailstones grow larger. However, as the altitude of the 0°-melting level is higher in a warmer atmosphere, the hailstones also have more time to melt before they reach the ground.

Combining the two effects, small hail would be less frequent in a warmer climate (as it melts before reaching the ground) but large hail would become more frequent (as additional water vapor and stronger updrafts allow the hailstones to grow larger)[7].

3 For example,
- Raupach, T. H., Martius, O., Allen, J. T., Kunz, M., Lasher-Trapp, S., Mohr, S., ... & Zhang, Q. (2021). The effects of climate change on hailstorms. Nature reviews earth & environment, 2(3), 213-226.
- Rädler, A. T., Groenemeijer, P. H., Faust, E., Sausen, R., & Púčik, T. (2019). Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. npj Climate and Atmospheric Science, 2(1), 30.
- Taszarek, M., Allen, J. T., Brooks, H. E., Pilguj, N., & Czernecki, B. (2021). Differing trends in United States and European severe thunderstorm environments in a warming climate. Bulletin of the American Meteorological society, 102(2), E296-E322.
- Berthet, C., Dessens, J., & Sánchez, J. L. (2011). Regional and yearly variations of hail frequency and intensity in France. Atmospheric Research, 100(4), 391-400.

4 ERA5 is the fifth generation ECMWF atmospheric reanalysis. Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... & Thépaut, J. N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146(730), 1999-2049.

5 Rädler, A. T., Groenemeijer, P., Faust, E., & Sausen, R. (2018). Detecting severe weather trends using an additive regressive convective hazard model (AR-CHaMo). Journal of Applied Meteorology and Climatology, 57(3), 569-587.
Rädler, A. T., Groenemeijer, P. H., Faust, E., Sausen, R., & Púčik, T. (2019), p 14. Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. npj Climate and Atmospheric Science, 2(1), 30.
Battaglioli, F., Groenemeijer, P., Púčik, T., Taszarek, M., Ulbrich, U., & Rust, H. (2023). Modeled Multidecadal Trends of Lightning and (Very) Large Hail in Europe and North America (1950–2021). Journal of Applied Meteorology and Climatology, 62(11), 1627-1653.

6 Battaglioli, F., Groenemeijer, P., Púčik, T., Taszarek, M., Ulbrich, U., & Rust, H. (2023). Modeled Multidecadal Trends of Lightning and (Very) Large Hail in Europe and North America (1950–2021). Journal of Applied Meteorology and Climatology, 62(11), 1627-1653.

7 Raupach, T. H., Martius, O., Allen, J. T., Kunz, M., Lasher-Trapp, S., Mohr, S., ... & Zhang, Q. (2021). The effects of climate change on hailstorms. Nature reviews earth & environment, 2(3), 213-226.

Although the increase of large hail events has not yet reached scientific consensus (it is still a relatively new field of research), this trend is consistent with both recent observations of record-sized hailstones[8] and the physical processes outlined above. We believe these elements provide sufficient impetus for the re/insurance industry to investigate these trends and their possible impacts on expected insured losses, ensuring the sustainability of re/insurance.

Method: Building a hail model

We have developed a stochastic hail model for Europe by combining the ESSL hail probabilities for each day from 1950 to 2022 with radar measurements, to provide information about the spatial extent of thunderstorms. By correlating hail probabilities to the area covered by thunderstorms in the radar data, we have created 100 plausible versions (stochastic simulations) of each day from 1950 to 2022, leading to a fully stochastic event-set with 7,300 years and about 80 million hail footprints over Europe.

For each footprint, we sample the hail size distribution by using the ratio of the probabilities for very large hail (>5cm) and large hail (>2cm). Therefore, the modeled hailstone sizes depend on the environmental conditions at each specific day. The model has been calibrated for Germany, France, Italy, Austria, Switzerland, Belgium, the Netherlands and Luxembourg, incorporating distinct vulnerability curves for property and motor exposure due to the substantial impact of motor losses on hail damages in Europe.

Result: Increasing annual aggregated hail losses from 1950 to 2022

When we base our event-set directly on the hail probabilities from the ESSL[2], annual aggregated modelled hail losses (AAL) are increasing, due to the underlying trend in the probabilities. As we created 100 versions of each day and year, we can apply an exponential fit through all the annual aggregate losses (Figure 2). The fit results in a 1.4% increase of AAL per year for France, which is equivalent to almost a tripling from 1950 to 2022.

Similarly, modelled hail losses increase in other European countries (see Figure 3 and Table 1): Italy has the highest AAL increase (+1.7% per year), while Germany displays the lowest year-to-year trend (+0.8% per year).

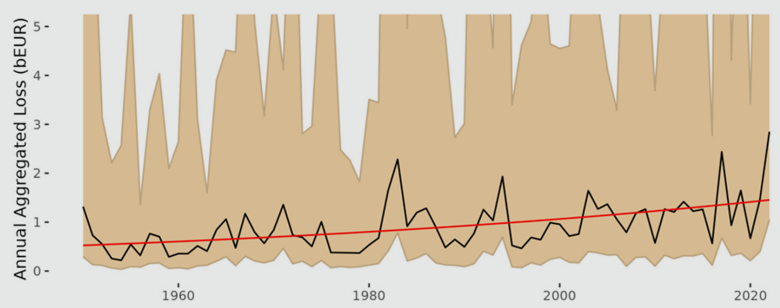

Figure 2: Modelled climate change influence on annual aggregate loss for French property market. Modelled annual aggregate loss depending on hazard analog year for present-day France property industry exposure and present-day cost level. Any inflation and exposure change over the years is not considered in this simulation, solely the change in hazard. The shading shows the range of all 100 versions of each hazard analog year (up to EUR 30 billion in the extremist year). The black line is the mean of all annual losses per hazard analog year. The red line is an exponential fit through all annual aggregate losses of each simulated year (7300 years).

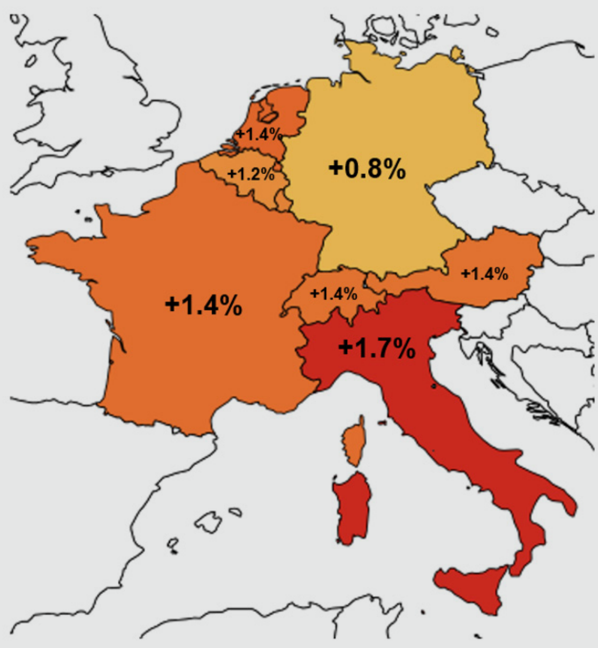

Figure 3: Annual increase in modelled hail annual aggregated losses. Estimated annual trend (% per year) in annual aggregate loss from 1950 to 2022 per country. Redder colours indicate higher annual trends (see Table 1 for an overview of the trends per country).

8 https://www.essl.org/cms/hail-record-broken-again-19cm-hailstone-confirmed-in-italy/, https://www.essl.org/cms/major-hailstorms-of-2022/

Consequence: Bringing the model to today's level by adjusting the older years upward

We believe these trends are primarily due to impacts of climate change (and should not be attributed solely to natural variability). Given the need to price today's risk, we adjusted original hail probabilities by bringing the older values to today's level (based on the fitted trends) and created our final, adjusted event-set based on these adjusted hail probabilities.

Thereby, our model represents present-day risk and not an average risk over the past 73 years. Compared to the modelled losses in the adjusted event-set, the original, unadjusted event-set underestimates the annual expected loss (AEL) by 30% in France, 25% in Germany, and 43% in Italy[9]. These differences are lower than applying the estimated annualized trend for 73 years since the magnitude of the adjustment is greatest for the oldest years and reduces in magnitude for the more recent years.

Changes of annual aggregated loss (AAL) per year and change of annual expected loss (AEL) from adjusting the event-set for climate change

Country	Estimated annualized trend (%). Change in AAL per year in original eventset from 1950 to 2022	Difference in AEL (averaged over all years) between adjusted (corrected for climate change) versus original eventset
France	+1.4%	+30%
Germany	+0.8%	+25%
Italy	+1.7%	+43%
Austria	+1.4%	+39%
Switzerland	+1.4%	+32%
Belgium	+1.2%	+36%
Netherlands	+1.4%	+37%
Luxembourg	+1.3%	+36%

Table 1: Per country, estimated annual trend (% per year) in annual aggregate loss (AAL), from 1950 to 2022 according to the exponential fit (see Figure 2) and change in AEL between the original (unadjusted) and the adjusted event-set[9].

Impacts on the re/insurance industry

- Our analysis suggests that hail losses have increased by 0.8% -1.7% per year across Europe over the past 73 years (see Table 1) due to underlying trends in the reanalysis predictors of hail probability.
- If we assume (as the scientific literature suggests[3]) that these trends are driven by climate change, our analysis shows that climate change is an important contributor (an estimated 20% to 55% of the total) to the annual expected change in risk of loss, compared to other changing risk factors such as exposure and inflation.[1]
- The industry should develop more scientifically rigorous catastrophe models (using similar methods) that account for climate change to accurately price today's risk.
- We expect this trend to continue, and the re/insurance industry must be prepared for climate change to meaningfully contribute to increases in Europe hail losses in the future

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9 These discrepancies occur when the same calibration is applied to both event-sets. If a model that does not account for climate change is calibrated against current losses, it will not have this magnitude of underestimation in the AAL.