COVÉA WHITE PAPER

Climate change and insurance: What effect will it have on claims between now and 2050?

JANUARY 2022

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PREFACE × PAUL ESMEIN

Covéa is proud to present you with this white paper on climate risk modelling. This exclusive study follows 10 years of work already carried out by the Group and was drawn up by teams from the Property and Casualty Department alongside RiskWeatherTech.

COP26 reminded us all of the scale of the challenge that climate change presents for the future of the planet.

As an insurer, Covéa is on the front line observing and measuring its consequences. For example, the number of claims in the French market has already tripled since the end of the 1980s, and all forecasts indicate that this trend will continue to grow sharply over the next decade.

We are therefore compelled to take firm action now, rather than waiting for countries to come up with their own solutions. We are all concerned – as company executives, employees, citizens, parents and other members of society. And we must all act to limit global heating by the end of the century and uphold the commitments made as part of the Paris Agreement.

Covéa has long been fully committed to combating climate change. Firstly, out of conviction, as finding solutions is the core to our work as a committed mutual insurance company, but also out of responsibility, as a leading provider of motor and home insurance in France.

Luckily, insurance companies can take action in various ways. We need to reduce our own emissions, with a low-carbon strategy for the day-to-day activities of our business. We must also change our investment policies and systematically make the environmental impact part of our criteria during decision-making. Lastly, we must change how we support our members through our insurance activities – for example, by repairing rather than replacing where possible, and encouraging reuse. All of these actions are key to our new strategic plan.

Our responsibility is to look at the world around us in a clear-eyed and pragmatic manner. To take effective action, we must understand and plan, including by modelling the impact that climate change will have on society as accurately as possible. This observation may not be reassuring, but it is fundamental and essential. Because, even though modelling inherently accounts for a certain degree of uncertainty, it is the only solution that will enable us to understand the adaptations and, more specifically, prevention measures we must undertake.

Covéa has been investing in the modelling of climate risk and extreme events in particular for over a decade. This white paper demonstrates that. We aim to persist with our research so we can continue to protect our members in a sustainable way. That will be a priority for the Group in the years to come.

PAUL ESMEIN
Deputy Chief Executive Officer of Covéa

PREFACE × VINCENT MORON

The idea that humankind was potentially responsible for the variability of our contemporary climate was evoked as early as the late 19th century, in response to the doubling of atmospheric carbon dioxide – long before the planet's average temperature began to significantly increase. It first began to rise – albeit to a limited extent – before the 1940s, then more intensely from the 1970s onwards. The earth's temperate has since increased by around 1°C. Global warming can no longer be denied, and the responsibility of humankind has been proven. Relevant natural climate forcings – such as sunlight and volcanic eruptions – in recent decades alone cannot explain the trend of rising temperatures seen over the last 50 years. Researchers like Wallace Broecker raised the alarm as early as 1975, warning that the lithosphere and hydrosphere would not be able to absorb immense CO_2 emissions, causing massive and unavoidable warming. Since then, climate projections have become more accurate. We can now look back on the first climate simulations from the 1990s, which only included human-caused drivers and were therefore relatively rudimentary, with 30 years of hindsight. Nevertheless, these forecasts have proven remarkably accurate in regards not only to increases in global average surface temperatures, but also their direct consequences – such as the average rise in sea levels, although the extent of this was underestimated. The latest scenarios are, of course, more accurate. We can now clearly assess both the quality of these potential future climates and the different conditions we may experience by the end of the 21st century.

We have now committed to major environmental management that involves society as a whole, with the aim of reducing greenhouse gas emissions, adapting to unavoidable changes resulting from inertia in climate systems, and trying to find innovative technological solutions to reduce the excess greenhouse gases already released into the atmosphere.

Climate change may seem inconsequential at the individual level – particularly when compared to cyclical variations, such as the cycle of day and night and the change of the seasons, which vary much more widely according to the part of the world in question. However, as this white paper points out, relatively slow but monotonous warming over at least a number of decades profoundly heightens the probability of various risks that are, by nature, rare, but may have drastic consequences for society and/or the environment. And the insurance sector is on the front line in all this. The Covéa white paper demonstrates that even minimal warming increases the likelihood of certain extremes. Some of these extremes are relatively common, such as drought, as heat increases the rate of evaporation in the air. Other less direct but now proven consequences, such as the link between global warming and the likelihood not only of more frequent dry spells, but also extreme rainfall, would have multiple harmful consequences on numerous economic sectors. Of course, initial efforts – even when modest, partial and insufficiently ambitious – to manage anthropogenic climate change, such as the Kyoto Protocol signed in 1997, have shown that worst case scenarios are not necessarily the ones followed. We have now committed to a more ambitious programme in line with the Paris Agreement, signed in 2015, and therefore hope that the global warming scenario known as "RCP8.5", referred to in this white paper, will not come to pass. Nevertheless, focusing on this worst case scenario seems logical, so that we may assess and anticipate the most drastic changes that could result from various climate risks. That way, we will be able to alert the insurer community to the potential extent of the consequences climate change may have on different sectors in the not-so-distant future.

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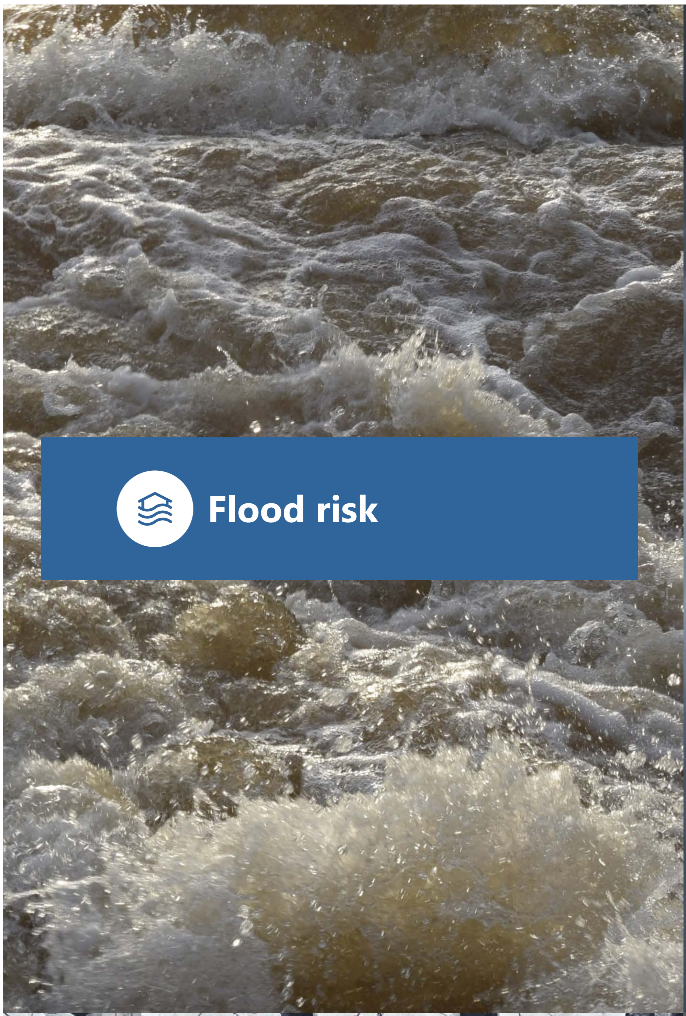


Flood risk

Windstorm risk

Subsidence risk

Hailstorm risk

INTRODUCTION

There can no longer be any doubts about the existence of climate change; it has been confirmed by the broad scientific consensus surrounding the work of the of IPCC.[1]
For insurance providers, accounting for climate change-related risks has proven to be one of the main challenges to the assessment and management of assets and liabilities in upcoming decades.

> *“Climate change is a systemic risk for the whole world.*
> *Unlike Covid-19, it doesn’t have an expiry date.”*
>
> **JÉRÔME JEAN HAEGELI**
> Group Chief Economist for reinsurer Swiss Re

In the context of climate change, insurers' liabilities will be directly affected by the increase of claims linked to a rise in weather events – whether in the form of major disasters (e.g. tropical cyclones, storms, etc.) or less dramatic but more frequent incidents (e.g. flooding, drought, etc.). However, the future's changing climate is subject to great uncertainty as regards the greenhouse gas emission (GHG) trajectories put forward by the IPCC, which strongly depend on socio-economic activities and the mitigation policies in place. The countries that signed the Paris Agreement at COP21 in 2015 agreed to take action to limit global warming to 2°C, but today, that scenario has already been largely abandoned. The most pessimistic scenario is currently the most likely, with global temperatures set to rise by around 2.4°C by 2050 and 4.8°C by 2100.

Globally, 2011 to 2020 is considered the hottest decade ever observed by the scientific community. It is also the decade with the highest number of claims made in the property segment.[2] This is certainly true in mainland France, where there has been a dramatic rise in claims linked to natural events since 2015, heralding the effects of climate change.[3] That year saw flash flooding strike the Côte d'Azur and the Cannes region after storms and heavy rainfall, generating damages amounting to over €500 million for the French market. In June 2016, the river Seine rose to exceptional levels, generating over €1 billion of damage. The year 2017 remains exceptional for claims, with two category 5 hurricanes, Irma and Maria, striking the islands of Saint Martin and Saint Barthelemy and incurring damages costing over €2 billion. A series of exceptional droughts then hit mainland France in 2018, 2019 and 2020. Claims in this market were estimated at around €1.3 billion and €1.1 billion for the droughts of 2018 and 2020, respectively.

The increase in the frequency of claims and their costs raise questions regarding governance, management and assessment of climate change-related risks in insurance companies' strategies for decision-making on pricing, underwriting, coverage and reinsurance capacity policies.

In 2020, growing concerns about climate risks led to the launch of a pilot exercise known as climate stress testing by the French Prudential Supervision and Resolution Authority (ACPR), which monitors the country's main banks and insurance companies. The aim of this unique exercise is to assess the awareness and interest of the Paris financial market in managing and accounting for climate change-related risks to ensure financial stability. What's more, EU supervisory authority EIOPA has also launched a consultation of European insurers' integration of climate change risks into ORSA scenarios.

Covéa leads the way in this area, and has proven particularly proactive in relation to climate risks since 2011. A team of cross-disciplinary experts (including geographers, climatologists, geomatics specialists and data scientists) was formed to develop a range of innovative modelling tools. Our internal Coventéo Catnat model is used to monitor and model climate risks and damages, in order to ensure effective management of risk exposure. In the initial models, hypotheses regarding the frequency and intensity of these incidents were based on historical observations of the climate made over the last 50 years. Today, taking action to tackle climate change is clearly essential.

Under the effects of climate change, **how will the frequency and intensity of natural incidents change between now and 2050? What will the consequences be for insured losses?**

To answer this question, Covéa and RiskWeatherTech teamed up to carry out a study with the aim of quantifying the changes expected to affect insured losses due to the risks of flooding, subsidence, hailstorms and windstorms as a result of climate change between now and 2050.

CLIMATE AND POPULATION FORECASTS

Analysing climate change and its repercussions on insured losses requires accounting for both the changing nature of the incidents in question, but also the various stakes involved (i.e. portfolio exposure).

Climate and hydro-climate projections will therefore enable us to quantify how the four natural hazards – windstorms, subsidence, floods and hailstorms – will change in the future, while population growth projections will identify how insured property will evolve. The different data sets are shown in the next few pages.

→ GREENHOUSE GAS (GHG) CONCENTRATION SCENARIOS

Global circulation (GCM) and regional climate models (RCMs) play a crucial role in understanding the potential spatio-temporal evolution of climate change in the future in response to natural and human climate forcings. Modelling the future climate involves forming hypotheses on how anthropogenic GHG emissions will change in the coming decades. These changes depend on multiple factors such as population growth, socio-economic development, technological progress and climate policy. In the IPCC's Fifth Assessment Report, scientists identified four GHG emission pathways, named Representative Concentration Pathways (RCPs) [**Figure 1**]. The four RCPs include two extreme scenarios, RCP2.6 and RCP8.5, and two intermediate scenarios, RCP4.5 and RCP6.0:

- RCP2.6 represents a world that has shifted to a low-carbon and environmentally friendly model, where global warming is likely to remain below 2°C above pre-industrial temperatures.
- RCP4.5 and RCP6.0 represent intermediate trajectories, where emissions continue to grow for a number of decades before stabilising by the end of the 21st century, then decreasing.
- **RCP8.5 represents a world with no GHG emission regulations, leading to a global temperature increase of 5°C by 2100. In light of current policies and the rises in global temperature that have already been observed, this is the scenario used in this study.**

→ THE EURO-CORDEX REGIONAL CLIMATE SIMULATIONS

EURO-CORDEX[4] is the European branch of the CORDEX initiative. It produces ensemble climate simulations based on multiple dynamical and empirical-statistical downscaling models (RCM) forced by multiple global climate models (GCM) from the Coupled Model Intercomparison Project Phase 5 (CMIP5).[1] While GCM simulations describe climate evolution at a large scale by using coarse-resolution information, RCM simulations, derived through climate-downscaling techniques, aim to represent regional- and local-scaleweather conditions with grid resolutions ofless than 50 km. EURO-CORDEX provides simulations for a historic (baseline) reference period and future projections up to 2100, with a 12.5 km grid resolution, available for four RCPs defined at the international level within CMIP5. We analysed a 'high forcing' or

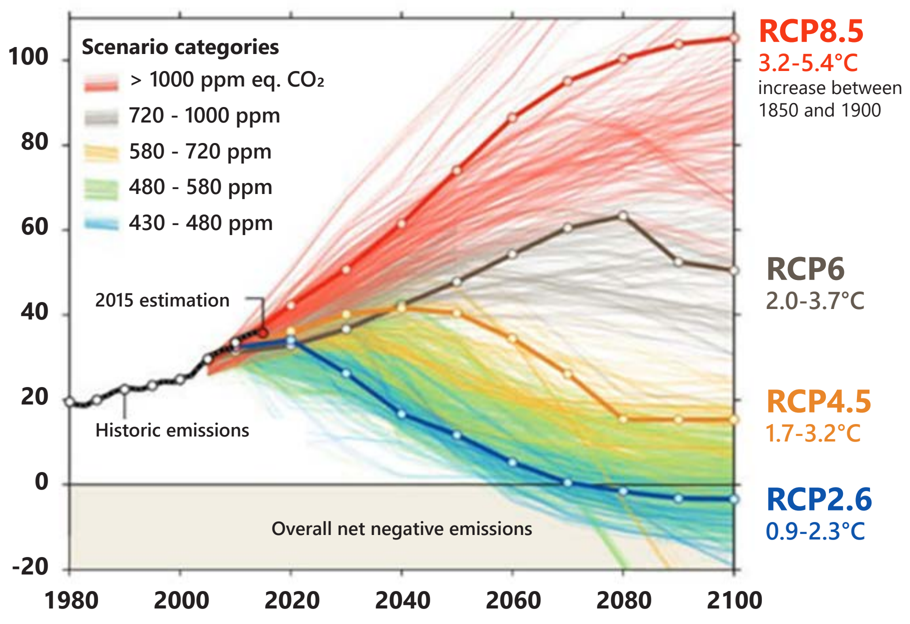


FIGURE 1

EMISSIONS GENERATED BY FOSSIL FUELS AND CEMENT ($GtCO_2$ PER YEAR)

Changes in emissions between 1980 and 2100, according to the various different scenarios available. The four RCP scenarios selected as part of the Fifth Assessment Report of the IPCC are highlighted.

Data: CDIAC/GCP/IPCC/Fuss et al 2014

'business-as-usual' Representative Concentration Pathway (RCP8.5), as it is consistent with observed global and regional warming trends.

Our final EURO-CORDEX multi-model ensembles, based on a combination of GCMs and RCMs, vary according to each natural hazard studied. We also only used RCM models that included the available climate data to precisely describe these hazards.

- A set of nine bias-corrected regional climate projections for daily precipitation for flood risk
- A set of six regional climate projections with the indicators needed to estimate hailstorm risk
- A set of six regional climate projections for daily wind gusts for windstorm risk
- A set of 11 regional climate projections indicating soil moisture for subsidence risk

Each of the EURO-CORDEX GCM-RCM pairs are outlined in more detail below in Table 1.

GLOBAL CLIMATE MODEL			REGIONAL CLIMATE MODEL			CLIMATE CHANGE-RELATED HAZARDS			
GCM	Institute	Country	RCM	Institute	Country	Flooding	Subsidence	Windstorms	Hailstorms
CNRM-CMS	CNRM	France	ARPEGE51	CNRM	France	●	●		
			ALADIN63	CNRM	France		●	●	
			CCLM4-8-17	CLMcom	International		●	●	
			RCA4	SMHI	Sweden	●			
EC-EARTH	Ichec	Europe	HIRHAM5_V1	DMI	Denmark	●	●		
			CCLM4-8-17	CLMcom	International	●			
			RACMO22E	KNMI	Netherlands			●	
HadGEM2-ES	MOHC	United Kingdom	RegCM4-6	ICTP	Italy				●
			HIRHAM5_V1	DMI	Denmark		●		
			CCLM4-8-17	CLMcom	International	●	●		
IPSL-CM5A-MR	IPSL	France	WRF331F	IPSL	France	●			
			RACMO22E	KNMI	Netherlands	●	●	●	
			REMO2015	GERICS	Germany		●		
			CCLM4-8-17	CLMcom	International				
MPI-ESM-LR	MPI	Germany	REMO2009	GERICS	Germany	●			
			CCLM4-8-17	CLMcom	International	●	●	●	
			COSMO-crCLIM-R1	ETHZurich	Switzerland				●
			COSMO-crCLIM-R2	ETHzürich	Switzerland				●
			RegCM4-6	ICTP	Italy				●
			ALADIN63	CNRM	France		●		●
Nor-ESM1-M	NMI	Norway	COSMO-crCLIM	ETHZurich	Switzerland				●
			HIRHAM5_v1	DMI	Denmark	●			
			REMO2015	GERICS	Germany		●	●	

TABLE 1 – List of EURO-CORDEX simulations used in this study, with the respective downscaled global climate model (GCM), regional climate model (RCM), and the natural hazard studied.

Climate projections cannot usually be used directly for impact studies at a fine scale, as these projections present biases when compared to observations. Using statistical methods to correct the biases in climate simulations is therefore essential in order to compare the results of projections with the current or past climate. Bias correction factors are estimated using observations and simulations of the current climate, with quantile-quantile or CDF-t methods.[5] They are then applied to climate projections, supposing that the biases presented by each model are identical in the current climate and future projections.

The multi-model approach presents a number of advantages in terms of objectivity and exhaustiveness as it accounts for all possible changes to the climate, with each model contributing to overall realism. The multi-model approach also filters the individual errors created by each model. Upon analysis, no particular weighting was given to any of the different models; this enabled a measurement of the consensus in the set of climate projections. Models included in this study are all considered to give equally likely projections, in line with the 'one model, one vote' approach. The models that we used do not all present the same internal climate variability or sensitivity; nor do they react similarly to climate change, with some modelling a drier or wetter future climate, drawing the multi-model approach upwards or downwards. One drawback of the multi-model approach is that it does not account for the climate signals in each model, reducing variability. In this study, two periods of time were chosen to represent climate change: the reference period or "current climate", which describes historical changes to climate parameters between 1970 and 2005 **(Reference period: 1970-2005); and the "future climate", which represents the climate modelled for the medium-term future (2030-2070) to project 2050.**

→ HYDRO-CLIMATE PROJECTIONS FOR THE SWICCA PROJECT

This set of simulations was created by the Swedish Meteorological and Hydrological Institute (SMHI) in collaboration with the EU's Copernicus programme.The SWICCA project aims to analyse the impact of climate change on river flow rates, using four EURO-CORDEX regional simulations and three hydrological models **[Table 2]**. The climate parameters – precipitation, temperature, wind, evapotranspiration, etc. – from EURO-CORDEX simulations have been included in the various hydrological models in order to estimate hydrological indicators, such as the duration of flooding, average monthly flows, soil moisture and peak flows. In this study, we looked at variations in flood discharge across return periods of 2, 5, 10, 50 and 100 years, between now and 2050.

TABLE 2 – List of EURO-CORDEX climate and SWICCA hydrological models used for flood analysis.

GLOBAL CLIMATE MODEL			
Hydrological models	GCM	RCM	Institute
E-Hypev3.1.2	EC-EARTH	RCA4	SMHI
	EC-EARTH	RACMO223	KNMI
	HadGEM2-ES	RCA4	SMHI
	MPI-ESM-LR	REMO2009	CSC
VIC-4.2.1.g	EC-EARTH	RCA4	SMHI
	EC-EARTH	RACMO223	KNMI
	HadGEM2-ES	RCA4	SMHI
	MPI-ESM-LR	REMO2009	CSC
Lisflood	EC-EARTH	RCA4	SMHI
	EC-EARTH	RACMO223	KNMI
	HadGEM2-ES	RCA4	SMHI
	MPI-ESM-LR	REMO2009	CSC

→ HYDRO-CLIMATE PROJECTIONS FOR THE CLIMSEC PROJECT

Hydro-climate projections were carried out as part of the CLIMSEC project[7] in order to plot the evolution of droughts under climate change. This comes in addition to the use of 11 EURO-CORDEX simulations. Regional simulations from the Arpège-Climat v4.6 (CNRM-Météo France) general circulation models, using GHG evolution scenarios and downscaled at a spatial scale of 8 km^2, were used with the Safran-Isba-Modcou hydrometeorological suite to obtain the monthly Soil Wetness Index (SWI). The SWI is considered the reference indicator to monitor subsidence under the CatNat insurance scheme for natural disasters. A number of socio-economic scenarios representing the climate policies in place and their repercussions for changes to the concentration of GHG were used in the Arpège-Climat model from 2000.[8] The SRES-A2 scenario was used for this study.

The various climate parameters modelled by these multiple climate projections enabled us to enhance Coventéo, the range of modelling tools for insured losses developed by Covéa [**Figure 2**].

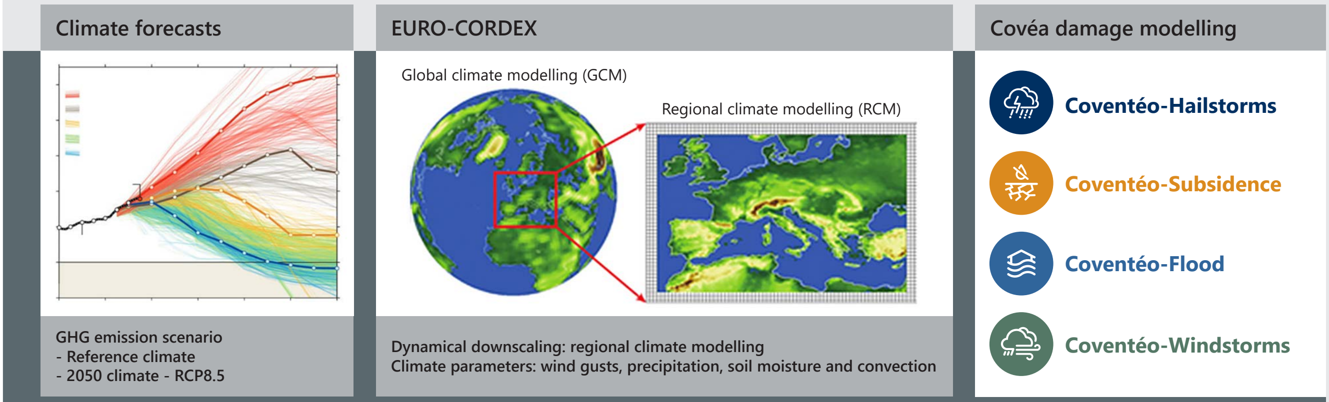


FIGURE 2 – Modelling chain for insured losses

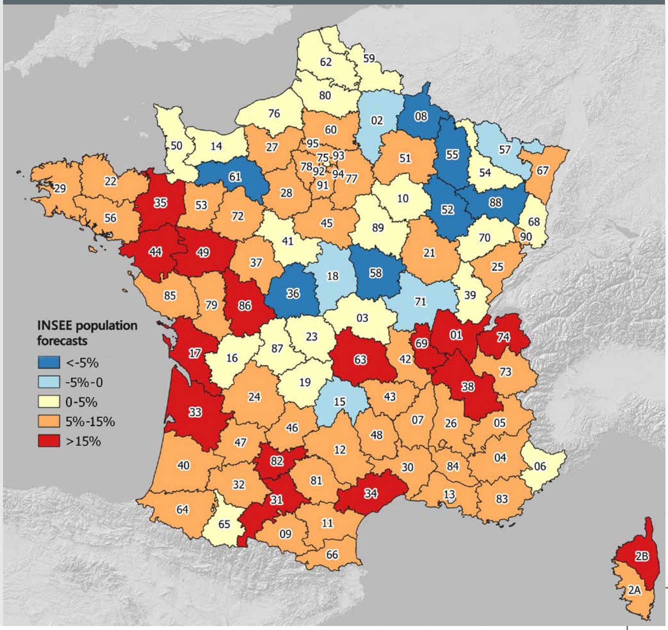
→ INSEE POPULATION PROJECTIONS FOR 2050

These population projections are based on the Omphale model,[9] which uses census data from 1 January 2013 for the population organised by sex and age. The forecasts are then carried out for all regions with over 50,000 inhabitants. The Omphale model effectively applies migration quotients between the areas people move from and to, as well as fertility and mortality rates for all sexes and age groups in the region in question. The various quotients were calculated by region in 2013. They went on to change afterwards, as the data at the national level extended recent fertility and mortality trends. Three scenarios – “low”, “median” and “high” – for population growth by 2050 were considered [**Figure 3**]. The median scenario was used here, and is based on the following hypotheses:

- The total fertility indicator reduced slightly, by 0.04, until 2016; from then on, it will remain stable until 2050.
- Mortality rates decline at the national level at the same pace, with life expectancy reaching 86.8 years for men and 90.3 years for women in 2050.
- Migration quotients between regions, calculated using 2013 census data, will remain constant throughout the forecast period. They reflect population flows between one region and all others, including French overseas departments (excl. Mayotte).

It should be remembered that changes to insured losses between now and 2050 were solely examined from the point of view of population growth and subsequent spatial dynamics. No assumptions for inflation or economic growth were applied to estimate changes to insured securities.

FIGURE 3 – Departmental forecasts of the population by 2050 according to INSEE’s median scenario



FLOOD RISK

Flood risk is the leading source of claims under the CatNat insurance scheme, with €21.6 billion of accumulated compensation allocated between 1982 and 2020.
In France, there are two types of flood caused by different weather events:
slow river floods and flash floods.

When rainfall is excessive, or maintained for an extended period of time, river flows increase and may overflow. River floods are when a river overflows onto a floodplain and an entire area is submerged, usually after a period of sustained rainfall. Flash floods are the result of heavy rainfall in a short period of time (i.e. under 24 hours). They are marked by very rapidly rising waters.

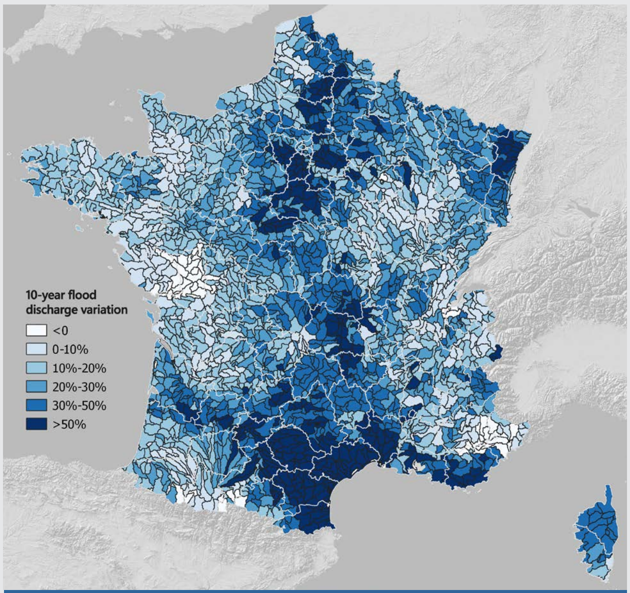
→ CHANGES TO THE RISK OF RIVER FLOODS

River floods are the result of sustained rainfall over a long period of time (e.g., several weeks), sometimes in combination with snow thawing from nearby hilly areas. These rainfall events can produce what are known as “slow” floods, which appear over a number of days and then last a relatively long time. Studying how this type of flood evolves requires hydrological modelling for catchment areas with rainfall events lasting a fairly long period of time.

To address this issue, hydro-climate projections for the SWICCA project enable a multi-model climate and hydrological approach, which reduces the level of uncertainty arising from the modelling of the forecast trends.

The changing reference flood discharges have been tracked for the 10-year return period between now and 2050 as part of the RCP8.5 scenario [**Figure 4**]. This return period corresponds with the threshold used by France’s interministerial committee to identify “abnormal” flooding. A general trend of increasing flood discharge has been observed in France, with very significant increases (>30%) in the South of France as well as a large part of the Northeast (incl. catchment areas for the Seine, the Saône, the Moselle and the Rhin rivers). The Atlantic and Channel coasts are expected to undergo moderate increases. Lastly, milder variations will occur in the Rhône river catchment area.

An estimation of the reliability of these changes is given via the average ratio or standard deviation in the set of hydro-climate projections. A value higher than 2 is generally considered to be a gauge of great reliability, while a value below 1 demonstrates a large spread of individual data from hydro-climate forecasts around the mean value. Flood discharge variation trends are highly reliable for most of France, but more uncertain for the Northeast of France. The increase of reference flood discharge flow rates is directly reflected by a shift of each return period to a lower return period. For example, what is currently a 100-year flood could, by 2050, become a 50-year flood.



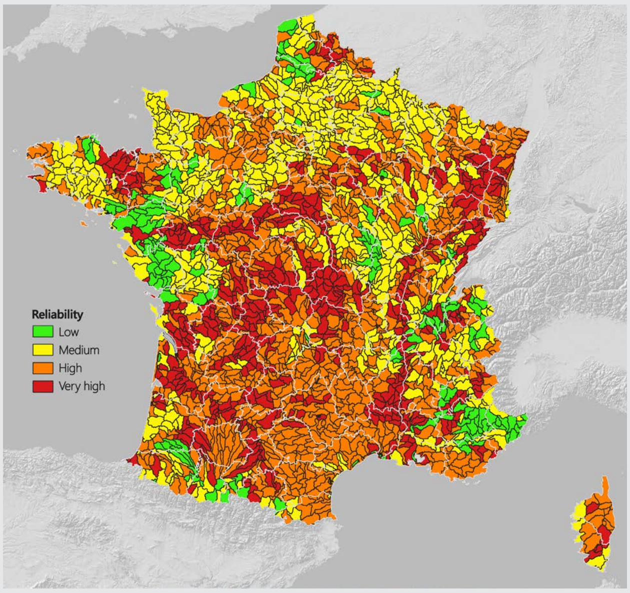


FIGURE 4 – LEFT: Variations in reference flood discharge over a 10-year return period (1/10 years) for each catchment area as a result of climate change between now and 2050.
RIGHT: Reliability indicator for changes calculated using the average ratio or standard deviation.

→ CHANGES TO DAMAGES LINKED TO SLOW RIVER FLOODING

The analysis of the impact of climate change on claims for river overflow floods was carried out using our Coventéo-Flood high resolution model and by requalifying the return periods for a certain number of reference floods (10-year floods, 20-year floods, etc.) between now and 2050 for the RCP8.5 scenario. We estimated the average annual loss (AAL) for each catchment area for the reference period (2008-2018) by creating an exceedance probability (EP) curve using budgets for 5-year, 10-year, 20-year, 50-year, 100-year and 200-year flood events.

The AAL calculation was carried out by modifying the reference flood frequency according to changing the discharge volumes simulated by SMHI's modelling work as part of the EU's SWICCA project. Using the linear relationship between the flood discharges and the logarithm of the return period, as in the Gumbel distribution,[10] makes it possible to recalculate a future return period for the reference discharge volume in line with its expected evolution.

A new EP curve can therefore be created using the new frequency values and INSEE's median scenario for population growth. Future changes to river overflow flood damages are expected to increase throughout most (50%-100%) French departments. Nevertheless, some regional differences have been observed [**Figure 5**]. The areas around the Atlantic coast and the catchment areas for the Rhône and Somme rivers are expected to undergo the highest increases of claims (>100%).

Losses linked to overflow could increase by 110% by 2050 for all of mainland France.

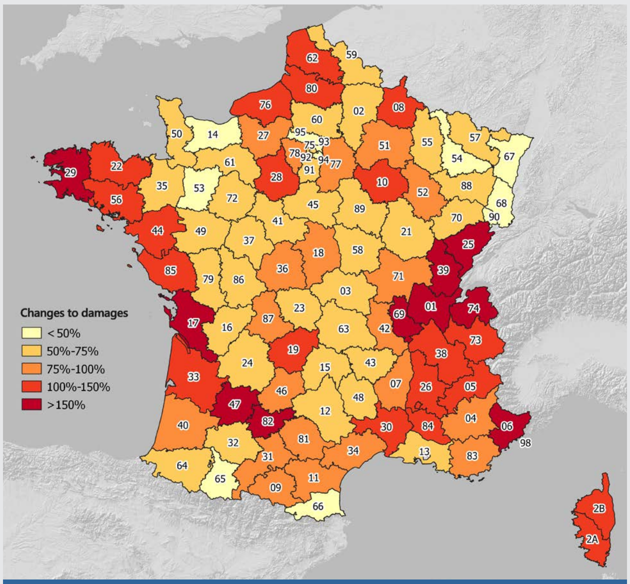


FIGURE 5 – Projected changes to future damages (using the average from the multi-model approach) due to river overflow floods. Changes to claims were calculated between the future period up to 2050 under the RCP8.5 scenario and the reference period (2000-2018).

50%
increase in flood discharges for the 10-year return period between now and 2050

110%
increase in claims by 2050

→ CHANGES TO RISK LEVELS FOR FLASH FLOODS

In France, flash floods mostly take place in the Mediterranean region. They occur following very heavy rainfall over a short period of time, generally exceeding 100 mm to 200 mm in 24 hours. These Mediterranean or Cévenol episodes are generated by depressions from the Mediterranean, which come up against the Cévennes mountain range or the Southern Alps, resulting in heavy thunderstorms along with heavy precipitation as seen in Draguignan in 2010, Cannes in 2015 and the Vésubie valley in 2020, to name just a few examples. In addition to these episodes, which are typical of the Mediterranean region, come various weather events linked to intense thunderstorms or fast-moving atmospheric depressions which, locally, can generate high volumes of heavy precipitation in low relief areas, leading to flood runoff events.

To assess future changes to heavy precipitation, daily accumulated precipitation data from nine EURO-CORDEX RCM simulations was analysed.

Changes in the frequency of intense precipitation and the annual probability of exceeding the various thresholds for daily precipitation corresponding to different return periods for the reference period were calculated for both the reference period (1970-2005), and between now and 2050 (2030-2070).

For each EURO-CORDEX model, each grid point was studied then aggregated for the sub-catchment areas using a calculation for the weighted averages of each surface area. The inter-model median values for each precipitation threshold are presented in **Figure 6**.

The precipitation thresholds analysed correspond to 10-year, 20-year and 50-year precipitation levels over 24 hours. It is customary to examine the thresholds for the 10-year rainfall for which rainwater drainage networks are calibrated when studying flood runoff. Beyond these thresholds, we consider that water from precipitation cannot drain away completely; there may therefore be runoff flooding. This analysis shows us that extreme precipitation events will increase in the future.

> On average, floods that currently occur once every 10 years will occur every 4.5 years, while 20-year rainfall will occur every 7 years and what is currently 50-year rainfall will take place every 11 years.

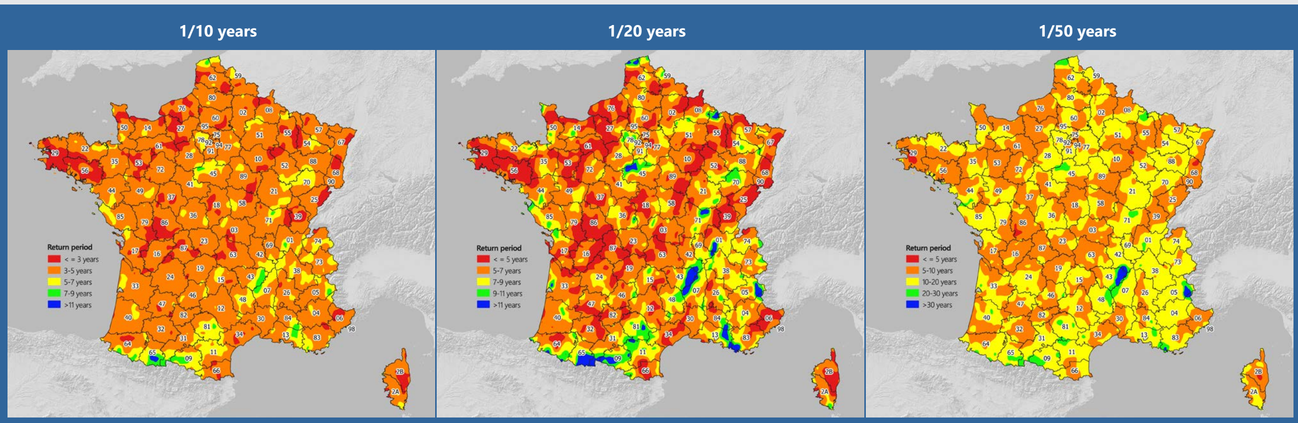


FIGURE 6 – Projected changes to the annual frequency that daily precipitation thresholds are exceeded using a multi-model climate approach (over 24 hours, by 2050, under RCP8.5)

→ CHANGES TO DAMAGES LINKED TO FLASH FLOODS

Estimating damages linked to flood runoff or flash floods involves meticulous analysis of historical claims (going back 15 years), which enabled us to apply different functions such as frequency and regional cost. The combined use of these damage functions with analyses of incident frequency enables us to calculate the average annual claims for the reference period and the time between now and 2050.

Future changes to flood runoff damages are expected to increase throughout mainland France. However, hot spots for claims linked to flood runoff do exist – including in the Charentes region, the Rhône valley and in Eastern France [**Figure 7**].

These claims are expected to rise by 130% by 2050, less updated costs, due to a significant increase in extreme precipitation.

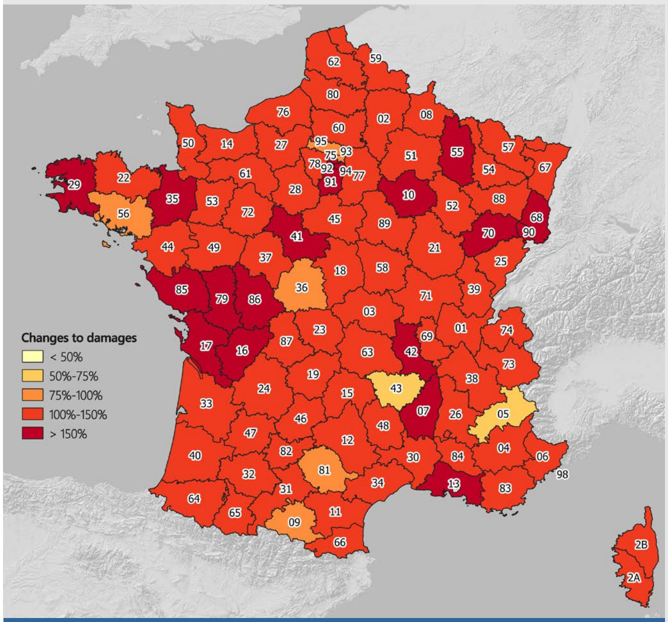


FIGURE 7 – Projected changes to average annual damages (using the multi-model approach) due to flood runoff. Changes to claims were calculated between the future period up to 2050 under the RCP8.5 scenario and the reference period (2000-2018).

130%

average annual increase in flood runoff and flash flood claims by 2050

Precipitation

1/10 > 4.5 years
1/20 > 7 years
1/50 < 11 years

WINDSTORM RISK

Aside from natural disaster insurance claims, storms are the most common type of insurance claim for the French property and casualty insurance market. Like other Coventéo "Cat" (disaster) models, the stochastic Coventéo-Windstorm model was developed on the basis of the frequency and intensity hypotheses obtained by analysing historical data. But the challenge is determining whether these hypotheses will still be valid between now and 2050 under the effects of climate change.

To answer this question, we took a twofold approach based on:

- An initial bibliographic review based on the analysis of scientific publications dealing with this subject
- A second study based on an in-depth analysis of six high-resolution EURO-CORDEX simulations

→ LITERATURE REVIEW

The literature review focused on the conclusions drawn in different IPCC reports,[1] and [8] as well as a range of peer-reviewed scientific publications.

We noticed that the scientific community had quickly reached a consensus on the changing windstorm risk in Europe. Many studies[8], [11], [12], [13], [14], [15] suggest that a more northerly track in the jet stream could deflect storms to the North. The IPCC reports[1] and [8] and work by by Chang et al.,[16] Zappa et al.[17] and Spinoni et al.,[18] based on CMIP5 climate simulations,[1] are consistent with the findings reported in previous studies.

Most climate models appear to show a potential northward shift in winter storm tracks due to a northward shift in the polar front and the jet stream as a result of rising polar temperatures and declining sea ice levels. However, the studies all cast doubt on the reliability of these findings, as the relevant climate model simulation results differ widely in the Northern Hemisphere. Climate models do not provide any clear indication as to whether phenomena will become more intense, although recent studies indicate that they might as a result of climate change. According to a recent study, sting jets[19] – an example of a meteorological phenomenon that can cause significant damage, as seen in the Great Storm of 1987 – could become more frequent due to climate change, particularly in Northern Europe. Another study, based on analyses of EURO-CORDEX simulations, indicates that climate change could lead to a marginal (0-20%) increase in the probability of extreme winds occurring between now and 2050.[20]

→ ANALYSIS OF EURO-CORDEX SIMULATIONS

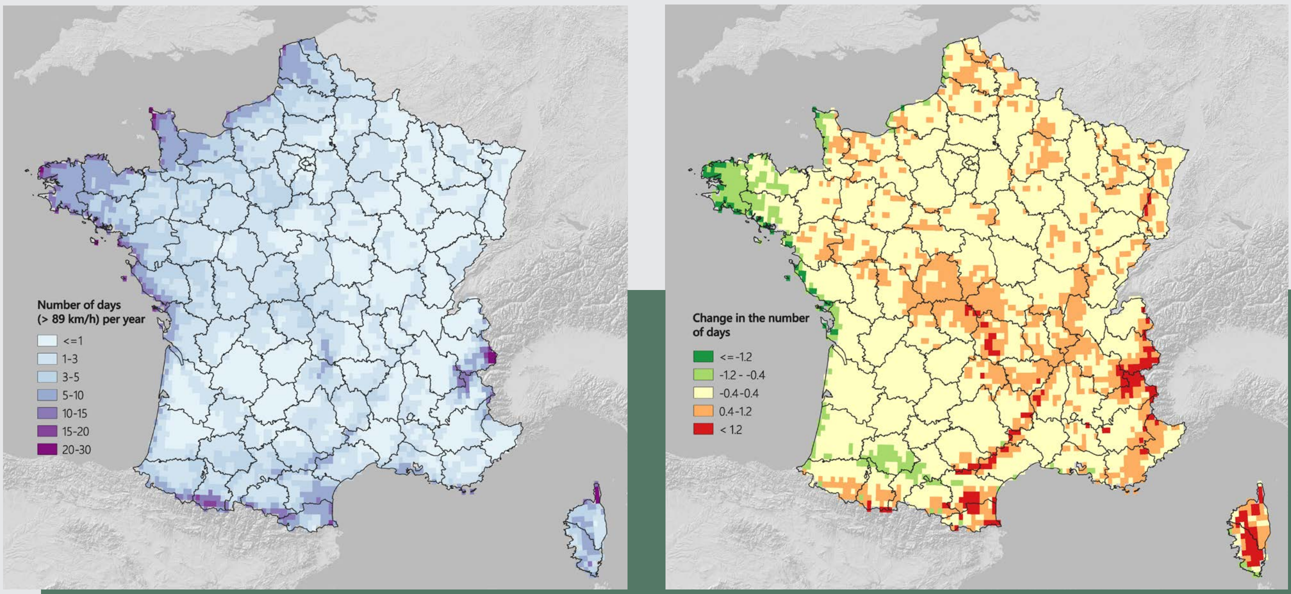


FIGURE 8 – LEFT: Frequency of stormy days (number of days per year with wind speeds of over 89 km/h) during the reference period (the mean of six EURO-CORDEX simulations). **RIGHT:** Projected changes to in the number of stormy days per year between the reference period and 2050 (the mean of six EURO-CORDEX RCM models).

In addition to the literature review, an assessment of local to regional-scale change in the frequency and intensity of extreme winds has been performed using EURO-CORDEX simulations.

A set of six GCM-RCM model combinations was considered **[Table 1]**. Analysis was based on a daily simulated maximum of 10 m gust wind speed.

Two analyses were carried out on these simulations:

- the first analysis was carried out to quantify the change in the annual frequency of storm days with wind speed above 89 km/h between the reference period and 2050; and
- the second analysis aimed to calculate changes in extreme wind speed (in km/h) from the 99th percentile distribution, with a view to analysing changes in storm intensity.

The multi-model ensemble mean climatology of the simulated (1975–2005) annual frequency of storm days exceeding 89 km/h is presented in [**Figure 8**] (left panel). Unsurprisingly, stormy days are more frequent along the Atlantic and Channel coasts. **Figure 8** (right panel) shows multi-model simulated anomalies in the number of stormy days between the 1975-2005 reference period and the 2050 future period. The region of Britanny presents a decrease in windstorm days, whereas most of mainland France presents a slight increase in windstorm risk. Nethertheless, the projected changes are mostly not statistically significant. The extent of these anomalies remains low, with a projected average change (increase or decrease) of three days per year in the future.

multi-model mean of changes in extreme wind speed (defined as the 99th percentile of daily maximum wind speed) for RCP8.5 (2030–2070) relative to 1975–2005 is presented in Figure 9 (right panel). A decrease of extreme wind speed could be expected over a large western part of mainland France in the future. Anomalies in extreme wind speed are very weak, at less than 5 km/h. On average, the magnitude of extreme windstorms should not change signficantly by 2050 **[Figure 9]**.

To conclude, our review of the literature and analysis of EURO-CORDEX simulations do not suggest any significant changes in storm frequency or intensity due to climate change between the reference period and 2050 under scenario RCP8.5.

No increase in windstorm frequency or intensity.

No significant increase in claims by 2050.

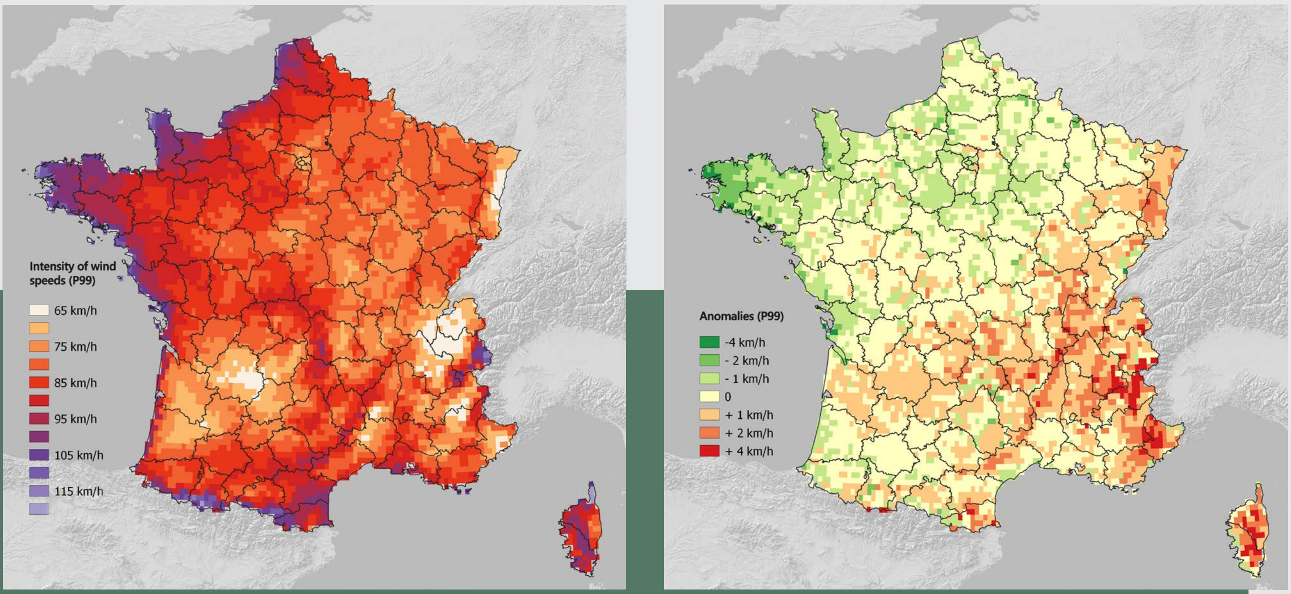


FIGURE 9 – **LEFT:** The 99th percentile of daily maximum wind speeds (in km/h) for the reference period.
RIGHT: Projected changes to the 99th percentile of daily maximum wind speeds (in km/h) between the reference period and 2050 (the mean of six EURO-CORDEX simulations).

SUBSIDENCE RISK

Geotechnical drought, subsidence and clay shrinkage and swelling are all synonymous with drought within the insurance industry.

Subsidence risk is defined as the displacement of the ground's surface due to the shrinkage and swelling of soils. It is mainly caused by the presence of clay in the soil, which swells in humid conditions and shrinks in dry ones. As a result, soil instability can cause substantial damage to the buildings above (e.g. cracks on the floor and walls) when their foundations are inadequate.

Subsidence damage is the second most common type of CatNat insurance claim after flooding. Between 1989 and 2020, drought-related insurance claims amounted to almost €15.2 billion.[3]

Since 2016, insurance providers have observed recurrent intense drought events and its ripple effect on the insurance industry. In a world marked by climate change, subsidence presents a major challenge for the insurance industry.

→ SUBSIDENCE RISK

The risk of subsidence occurring depends on a combination of factors related to changes in the moisture content of clay soils in response to changing weather conditions. Several factors of instability can contribute to subsidence:

Predisposing factors: The type of soil is the main predisposing factor. Clay soils are vulnerable to subsidence owing to their unusual "layered" mineral structure. Water molecules and ions in the interlayer space cause these soils to swell and shrink. The soil's plasticity therefore depends on its mineral content. "Expansive clay soils" contain minerals particularly prone to shrink-swell behaviour, such as smectite, vermiculite and montmorillonite. Forty-six percent of mainland France faces a moderate to high risk of clay shrinking and swelling, accounting for 93% of related insurance claims [**Figure 10**].

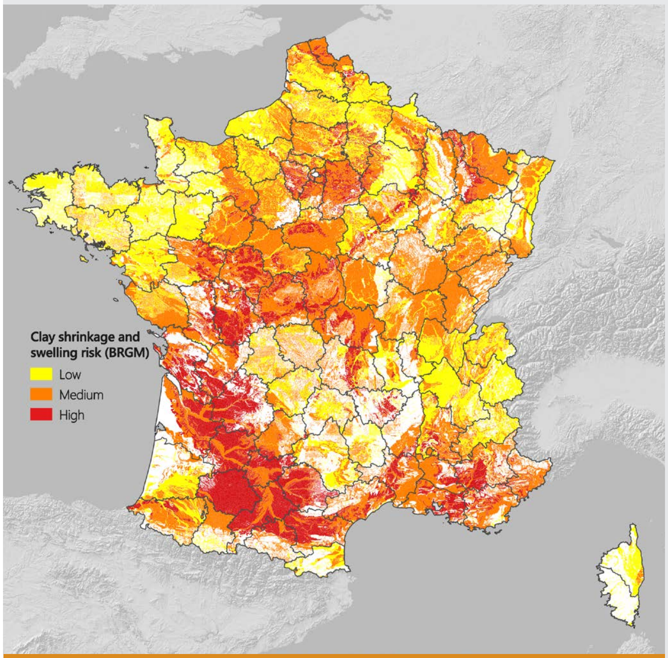


FIGURE 10 – Clay shrinkage and swelling risk map, updated in 2019 [BRGM].

Triggering factors: These factors cause soils to shrink and swell but only have a significant impact when coupled with predisposing factors. Soil moisture levels have a direct influence on clay soil structure. Changing weather conditions are the main initiating factor. The two main parameters are precipitation and evapotranspiration. During periods of exceptionally dry weather caused by a rainfall deficit and abnormal evaporation rates, the upper layer of the soil contracts. The water molecules are released from the interlayer space, leading to subsidence. During periods of wet weather, soils absorb water and clay swells.

Aggravating factors: Anthropogenic and environmental factors cannot cause subsidence on their own, although they do aggravate it. Anthropogenic factors include development work that may affect subsoil water content, drainage work, pumping, planting, leaks, burst underground water pipes and rainwater infiltration, which can have a significant impact on subsoil moisture levels and, consequently, cause disturbance when clay soils swell. **Environmental factors** include the presence of trees near a building constructed on expansive soils, which is an aggravating factor in and of itself as the roots extract water from the soil.

→ DROUGHT UNDER THE CATNAT INSURANCE SCHEME

CatNat insurance cover against drought-related damage has widely evolved over time. For instance, CatNat declaration criteria have changed eight times since 1989, which is why the list of past declarations and claims is heterogenous and difficult to analyse. In 2019, new declaration criteria[21] were introduced for droughts. These criteria now apply to all droughts from 2018 onwards. A town's eligibility for CatNat cover is based on two criteria:

A geotechnical criterion, which relates to the presence of clay soils vulnerable to subsidence and has been used since 1989. **At least 3% of a town's total surface must be prone to subsidence** to fulfil this criterion. This criterion identifies areas predisposed to subsidence events based on changes in soil moisture levels. It uses data produced by BRGM, the French geological survey. However, the intensity of shrinkage-swelling is not only due to soil characteristics but also to weather conditions.

A meteorological criterion is therefore used to assess the level of moisture deficit in the superficial soil. It is considered to be an initiating factor. The following criterion has been adopted:

- A single hydrometeorological variable: soil moisture levels using the soil wetness index (SWI)
- A single threshold for "abnormal" drought conditions under Article L.125-1 of the French Insurance Code. The administrative authority deems the intensity of a drought event to be abnormal when soil moisture levels indicate a return period **greater than or equal to 25 years**.

The criterion will be assessed once per season per year. Four indicators are therefore defined per year.

→ SPATIO-TEMPORAL CHANGES IN DROUGHT PATTERNS BY 2050

The temporal and spatial changes in soil moisture for each season between the current climate (reference period: 1970-2005) and the future climate (2050: 2035-2065) under the RCP8.5 scenario are shown in **Figure 11**. Droughts are expected to intensify for each season across the country. However, some parts of mainland France will be more affected than others according to the season:

- In winter, the decrease in soil moisture will be more marked in Brittany and the northern half of France than elsewhere in the country.
- In spring, the largest decrease will be seen in the Southwest, the Loire valley and the Paris Basin.
- In summer, the most significant decrease will be in areas along the Atlantic coast, the Southwest and the Provence-Alpes-Côte d'Azur region.
- In autumn, there will be a marked decrease in soil moisture in the western half of France, particularly in the Massif Central highland region.

The results therefore indicate that soil moisture will decrease in regions where they are currently quite high (e.g. Brittany, Massif Central and the Channel coast).

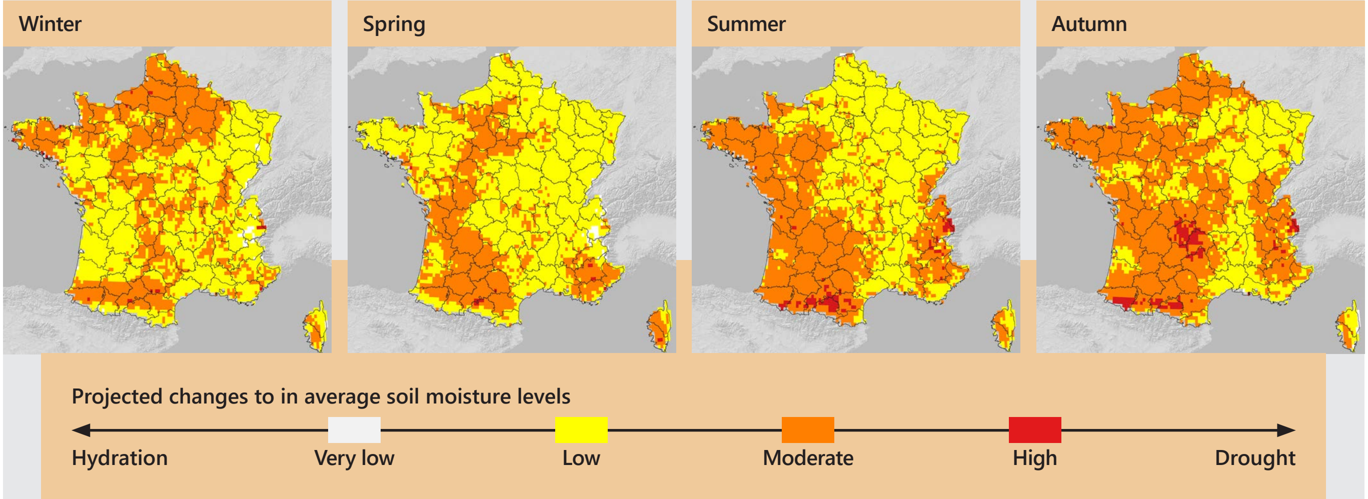


FIGURE 11 – Projected changes to seasonal soil moisture based on the RCP8.5 scenario for the 1970-2005 reference period and the 2035-2065 future climate (the mean of 11 EURO-CORDEX and DRIAS RCM models)

→ CHANGES IN THE NUMBER OF ELIGIBLE CATNAT CLAIMS AND ASSOCIATED DAMAGES

Figure 12 shows the changes to the annual frequency of hydrometeorological eligibility calculated using the multi-model soil moisture index exceeding a return period of 25 years by 2050 under RCP8.5. Regional differences in changes to the annual frequencies of CatNat eligibility can be observed. Although severe drought will be more frequent across the whole of mainland France, the Mediterranean, Southwest, Atlantic coast, Brittany and Grand Est regions will record the strongest expected increases (>100-150%).

Overall, an increase in the CatNat eligibility frequency of around 70% (mean of 11 EURO-CORDEX and DRIAS simulations) can be expected in the future (2050).

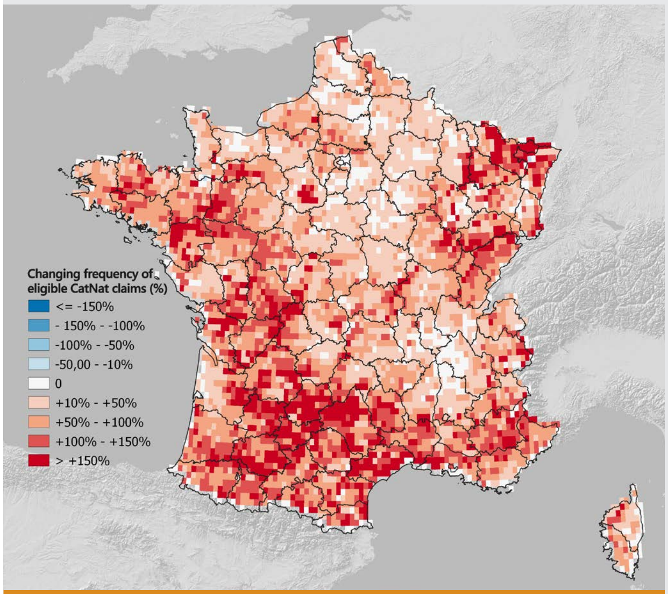


FIGURE 12 – Projected changes to the average number of eligible hydrometeorological insurance claims (return period > 25 years) per year between the reference period and 2050 (the mean of 11 EURO-CORDEX and DRIAS simulations)

Potential losses were calculated using a subsidence damage model – COVENTEO-Subsidence – which was developed by the COVEA team, based on the CatNat Scheme and calibrated from our own subsidence claims. The number of potentially eligible claims was calculated for each year between 2008 and 2065 for each of the 11 EURO-CORDEX and DRIAS simulations. The average was then calculated in line with a multi-model approach. The reference number of claims was calculated for the period 2008 to 2018 using an "as-if" approach. Furthermore, inflation was not applied to Covéa portfolios for two reasons: firstly, the number of high-risk homes had already been established for the next 30 years; secondly, damage to buildings less than 10 years old is covered under special liability insurance policies.

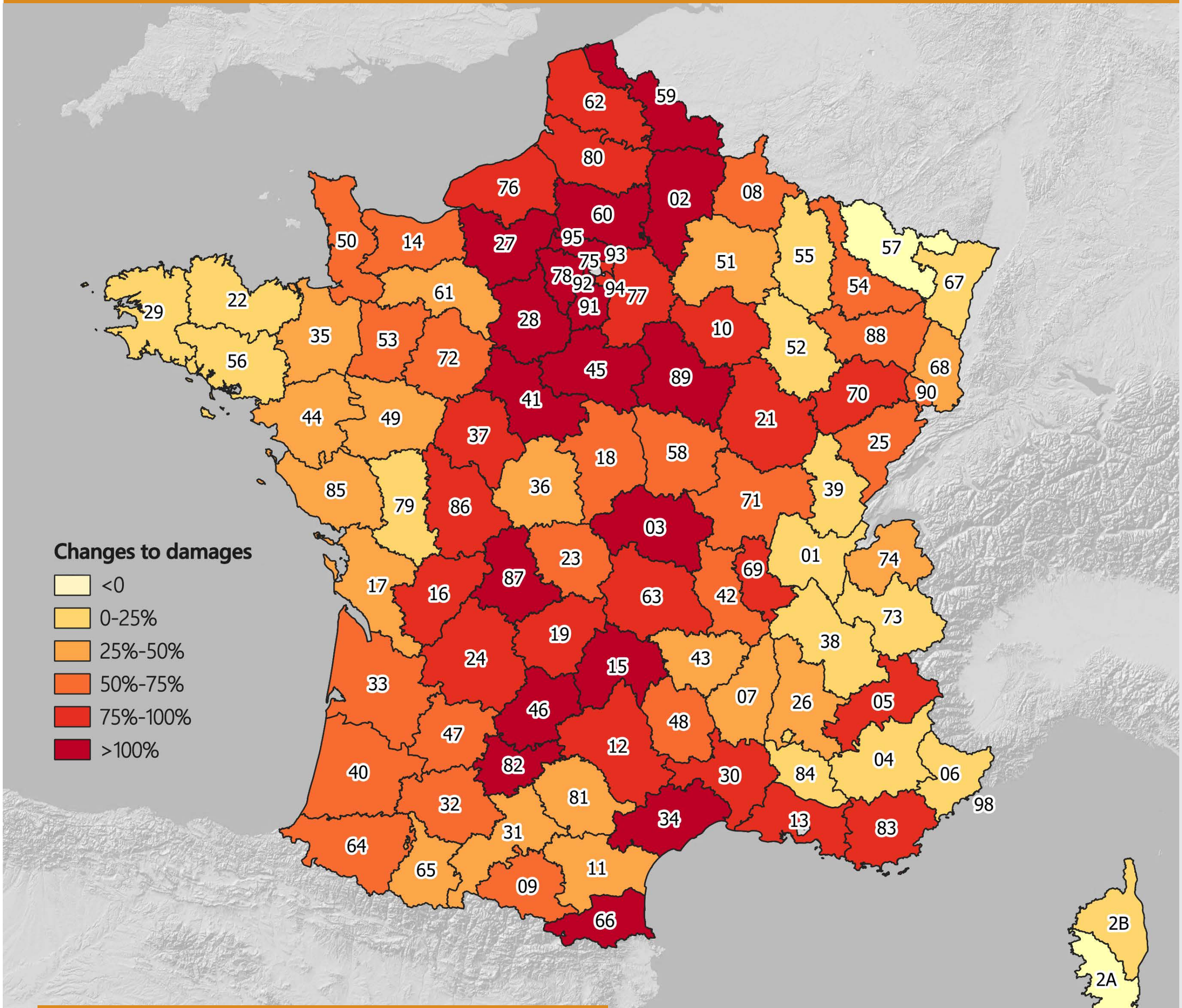
The 11 models were used to estimate the number of claims for each of the 58 years under the future climate scenario. The average losses were then calculated for 2050. The average annual change between the reference period (2008-2018) and 2050 was computed using the following formula:

$$\Delta AL= \left(\left(\left(\frac{\overline{AL\ 2050}}{\overline{AL\ ref}}\right)\right)-1\right)*100$$

$\overline{AL}_{2050}$	the average annual losses under future climate conditions (2045-2055)
$\overline{AL}_{ref}$	the average annual losses under the current climate conditions (2008-2018)

Multi-model subsidence-related losses are expected to increase by around 60% by 2050. The level of damage caused is expected to increase across mainland France, with some geographical differences [**Figure 13**]. The most marked changes are expected to be seen along the arc formed by the Var department, Toulouse and the Loire Valley. The Paris Basin, the Hauts-de-France region, the Burgundy region and the Limagne plain are also expected to be insurance claim "hotspots", with a significant increase in subsidence-related damage due to climate change.

FIGURE 13 – Projected changes to the damage (multi-model average) caused by subsidence between the reference period and 2050 under the RCP8.5 scenario.



70%

increase in
the number of eligible
CatNat insurance claims
related to subsidence

60%

increase
in claims
by 2050

HAILSTORM RISK

Hail is difficult to observe and identify using different atmospheric parameters. Research on the impact of climate change on hail was not available until 2015, primarily because the methods used to identify the conditions required for hail in reanalysis data must be approved upstream before they are adapted to climate projection data.

Covéa has developed a probability model for hail damage claims. Its frequency, spatial coverage and intensity hypotheses are based on a hailstorm indicator calculated using ERA5 reanalysis data (produced by the European Centre for Medium-Range Weather Forecasts) for the period 1979 to 2020. This indicator was used to identify all of the hailstorms that occurred during the period under review and establish a frame of reference for frequency and spatial coverage. It was also used to chart distributions relating to the direction of the hailfall based on the size of the marks left on the ground and the intensity of hail.

→ DEFINITION OF THE HAILSTORM INDEX

The approach used to analyse changes in hailstorm frequency was adapted from the work of Pucik et al.[22] and Rädler et al.[23] These researchers used two different meteorological indices to identify intense convective events causing hailstorms – the lifted index and vertical wind shear. For the second index, the directional shear was used rather than the speed shear in order to identify situations conducive to whirlwind phenomena, which significantly contribute to the increase in convective storm intensity.

The lifted index is computed as the difference in temperature between two vertical pressure levels – 850hPa (convective cloud base) or 700hPa (to limit the impact of mountain terrain) and 500hPa.

The directional wind-shear is calculated based on zonal and meridional winds between two levels of atmospheric pressure, the upper level being 500hPa and the lower level 850hPa or the surface. This index is only meaningful when used in combination with the lifted index, as it contributes to the scale and duration of the phenomenon. The directional shear is only an amplifying factor, not an index linked to the occurrence of this convective phenomenon, an initiating factor.

→ CHANGES IN THE FREQUENCY OF HAILSTORMS BETWEEN THE REFERENCE PERIOD AND 2050

The research carried out by Rädler et al.[24] uses EURO-CORDEX projections with a spatial resolution of approximately 45 kilometres. In our study, we considered an ensemble of 6 high-resolution EURO-CORDEX RCM simulations with a horizontal spatial resolution of 0.11° (~12 km). RCM models are detailed in **[Table 1]**. We used high-resolution models capable of resolving local and short-lived convective processes, such as hail. Two atmospheric index representing convective instability, Lift Index (LI) an directionnal wind shear, have been computed. The optimal thresholds for these two combined indexes were obtained from existing EURO-CORDEX simulation data using a convergence research method, the target value of which corresponded to the average number of days of hail per year in France – 67 days (source: Météo-France, France's national meteorological service) between April and October. This iterative method was used to determine cut-off values of -5°C for the lifted index and 90° for the directional shear, leading to a multi-model average of 66.6 days of hail per year. These cut-off values were then applied to climate projections for 2050.

The results indicate a significant increase of approximatively 40% in hailstorms across France [Table 3].

EURO-CORDEX MODELS							
Scenarios	MPI/COSMO-R1	MPI/COSMO-R2	MPI/REGCM4-6	HadGEM2/RegCM4-6	MPI/ALADIN63	Nor/COSMO	Average
Reference period	80.19	74.81	33.5	51.19	77.54	82.27	66.6
2050 [RCP8.5]	99.3	97.8	60.3	85.1	100.9	106.1	91.6
Increase	24%	31%	80%	66%	30%	29%	**38%**

TABLE 3 – Expected increase in hailstorms by 2050 based on six EURO-CORDEX RCM models.

In the northern two thirds of France, the number of days of hail per year will increase significantly – by one to four days – between the reference period and 2050. In the south of France, an area already greatly affected by hailstorms, the increase is not marked enough to be considered significant, although all models show a large increase in the number of days of hail.

The results of this analysis were then applied to the hailstorm frequency map developed by Covéa from the ECMWF ERA5 reanalysis dataset, which provides a basis for generating stochastic events within the probability model. We then applied local contributory factors to the map illustrating past figures to make spatial frequency projections for 2050 [**Figure 14**]. On the whole, large spatial changes in the regions worst affected by hailstorms are not expected to occur, although there will be a north-eastward shift in the distribution of areas that are very prone to hailstorms. Hailstorms are expected to increase significantly across all regions.

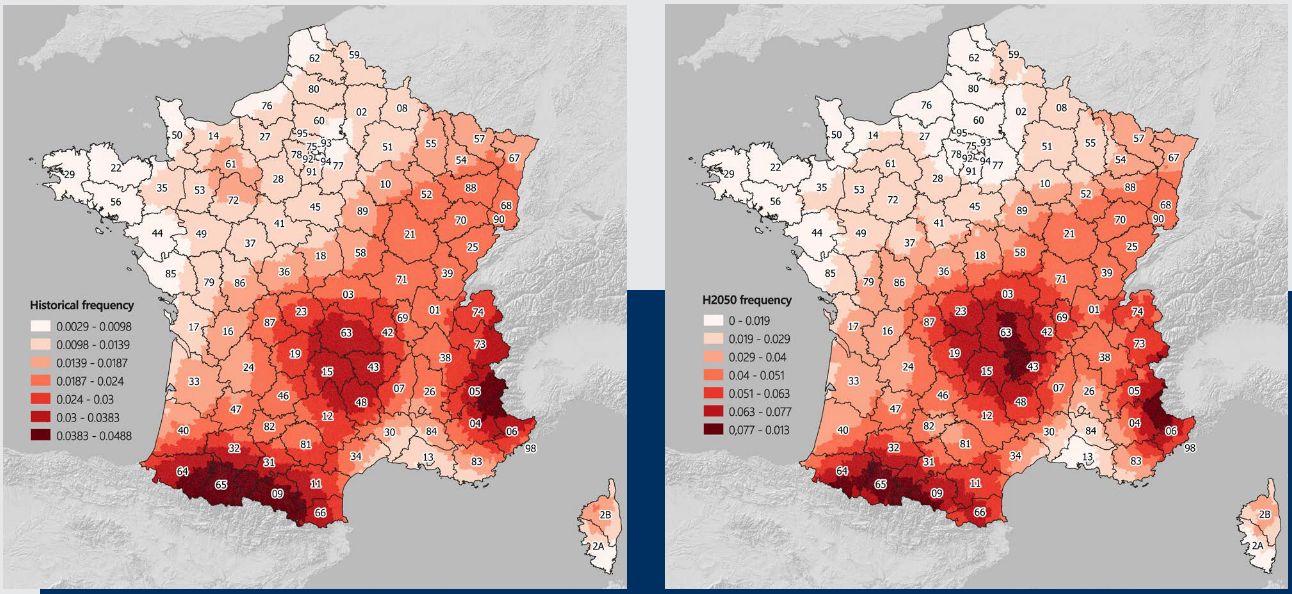


FIGURE 14 – A side-by-side comparison of the spatial frequency of hailstorms (expressed as the number of hailstorms per year) during the reference period and in 2050.

→ FUTURE CHANGES IN THE NUMBER OF CLAIMS

The expected impact of the increase in hailstorms on motor and property claims was assessed using the Coventéo-Hail stochastic model [**Figure 15**]. The new annual frequency values, estimated based on previous work, were injected into the hazard module to correct the existing model's stochastic event set and take account of the spatial redistribution of hailstorms due to climate change. In addition to correcting the stochastic event set, we assessed the spatial redistribution of risk exposures by applying INSEE's main forecasts to a "market" portfolio. These new portfolios (Motor and Property) were used in our stochastic model once the event catalogue had been corrected for the expected changes in spatial frequency due to climate change.

Hail-related motor and property claims are expected to increase by around 20% overall. This increase is partly due to an increase in the risk and partly due to the spatial redistribution of risk exposure.

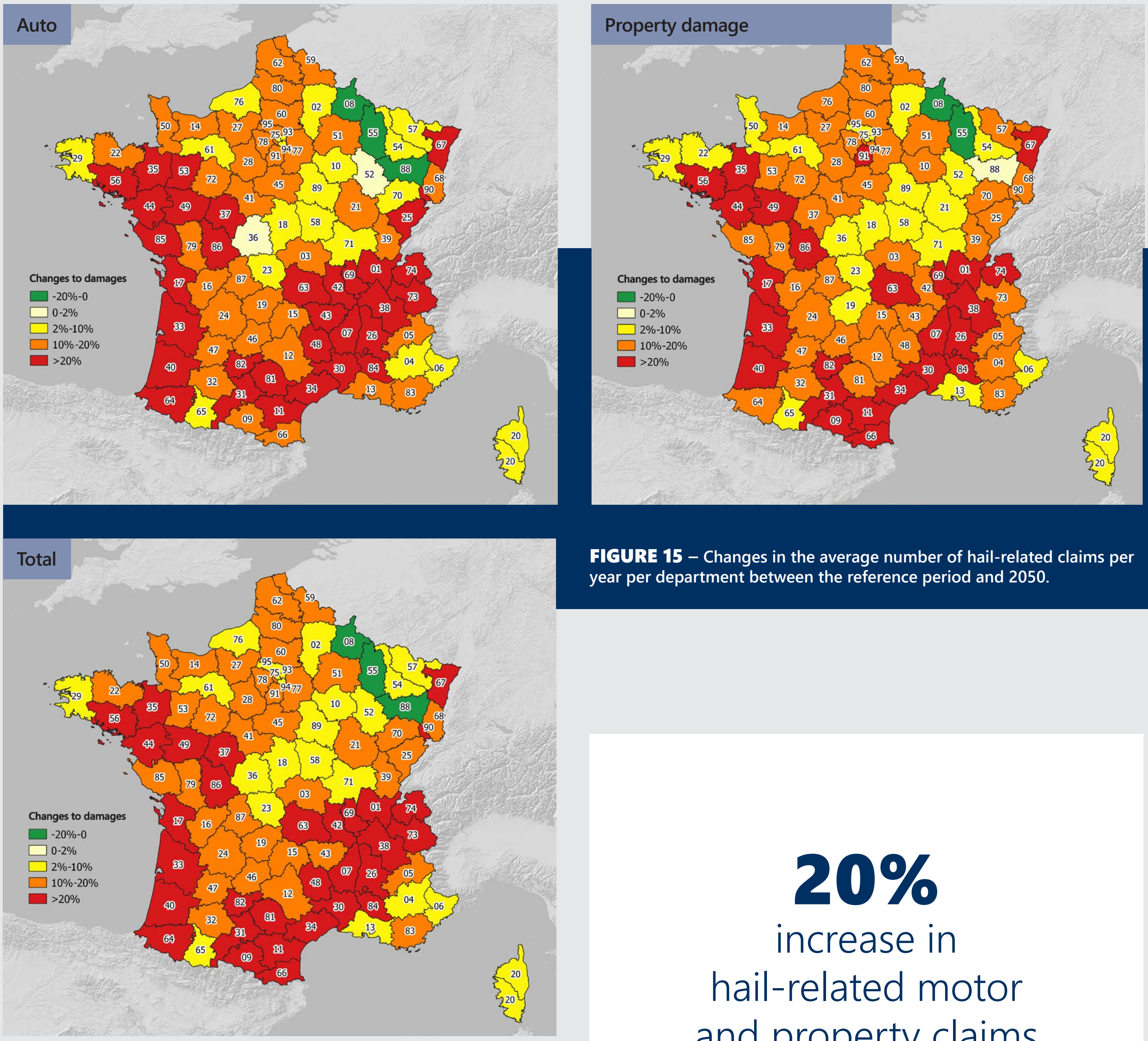


FIGURE 15 – Changes in the average number of hail-related claims per year per department between the reference period and 2050.

20%
increase in
hail-related motor
and property claims
by 2050

40%
increase
in hailstorm
frequency
by 2050

CONCLUSION

This study, carried out by RiskWeatherTech and Covéa, aims to shed new light on the impact of climate change on the future of insurance claims under scenario RCP8.5, a few months before the IPCC publishes its Sixth Assessment Report.

Our main conclusions for 2050 are as follows:

- Floods will occur more frequently across France due to a change in rainfall patterns – the average number of floods per year will increase in the northern two thirds of the country, whereas flooding will be less frequent but more intense in the southeast. Flash floods and riverine floods will therefore be more frequent and intense. Claims related to slow-onset floods are expected to increase by 110%, whereas those related to flash floods and associated flows are expected to rise by around 130%.

- The number of drought-related claims is expected to grow by around 60%. The number of eligible hydrometeorological insurance claims is expected to increase by 70% across mainland France.

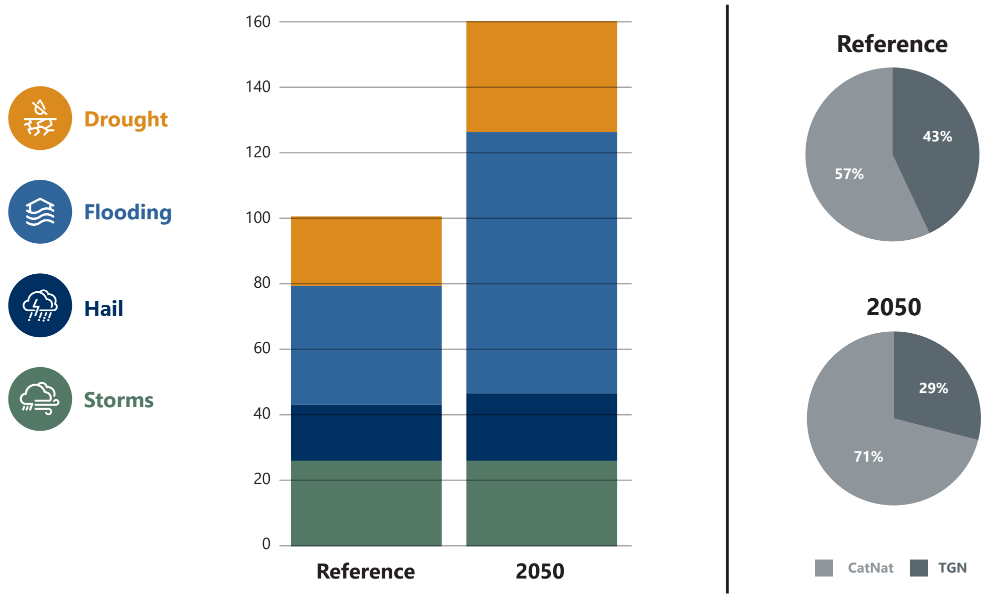
- The number of hailstorms is projected to increase considerably (by 40%) throughout France, including in areas that have not been prone to such events in the past. The northern half of France will see the largest increase in hail events, while the most hail-prone areas will remain unchanged. The number of claims is expected to increase by 20%.

- The only good news relates to storms – the number of stormy days and wind gust intensity are not expected to increase significantly over the coming decades.

- Overall, climate change is expected to lead to an increase of over 60% in claims in the coming years, with flooding, drought and hail events becoming more frequent and severe.

- The ratio of weather events that fall under the CatNat insurance scheme to those covered under "TGN" (storm, hail, snow) policies is expected to change. It was 57:43 during the reference period (1989-2019) and is expected to be 70:30 in 2050 [**Figure 16**].

FIGURE 16 – Breakdown of weather event claims [base value: 100] - Reference period vs. 2050



The conclusions of this study corroborate those of previous analyses by CCR[3] and FFA[25], indicating a general increase in weather event claims. However, the estimates made differ, particularly for flooding and droughts.

These differences can easily be explained by the fact that different methodological approaches were adopted:

- Our study is based on a multi-model approach that uses a much wider range of climate models than the FFA study; we used between 6 and 11 climate models according to the natural hazard analysed.

- Our risk modelling approach is in line with the regulatory requirements chosen as part of the CatNat insurance scheme.

- We used our own damage probability models – calibrated to reflect our experience with claims and our portfolios – to determine how risk-related changes might translate into claims.

The lack of assessments focusing on the relationship between climate change and hail-related claims makes it difficult to compare our conclusions with anything other than scientific publications.

These indicators highlight the challenges that climate change presents to insurers and, indeed, all other decision makers.

The Covéa Group has been using an innovative climate risk modelling solution – Coventéo – for over 10 years in order to better manage natural hazard claims. It will be more important than ever for non-life insurance providers to understand the relevant technical fundamentals. That is why Covéa is constantly working to improve its policies, ensuring greater consideration is given to risks when it comes to pricing, portfolio supervision and risk selection.

However, underwriting capabilities must extend beyond the traditional focus of risk pricing, supervision and selection. Prevention needs to be a core pillar of efforts to ensure housing can withstand the impact of climate change. Covéa has been a trailblazer in this respect by implementing a system that sends severe weather warnings to policyholders.

A research programme aims to develop solutions to adapt housing and ensure it can better withstand hazards in the future. For instance, tests are being carried out on equipping homes in flood-prone areas with watertight doors and cofferdams in accordance with the regulatory recommendtions set out in local risk prevention plans. Covéa is testing innovative drought-related solutions to mitigate clay soil subsidence using clay treatment processes and environmentally friendly soil rehydration methods during periods of water stress.

Given that climate risks are only expected to accelerate, insurance providers will no longer be limited to playing a “provider/payer” role – they will become increasingly committed to and proactive in monitoring and managing climate change-related risks to minimise the negative impact thereof on risk exposures and claims.

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