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Insuring a more open world

DIALog

Digital insurance and long term risk

Chaire d'Excellence

Green Book

Climate Risk and its Impact on Insurance

Executive Summary

FORWARD

We all measure it on a daily basis: climate change is accelerating, threatening human lives, property and the entire economy.

Recent reports from the World Health Organisation (WHO) are unequivocal. 3.6 billion people already live in areas highly sensitive to climate change - that's half of humanity. Between 2030 and 2050, climate change is expected to cause around 250,000 additional deaths each year.

Climate risk challenges the models used by actuaries, who are experts in quantifying risks, and CNP Assurances' mission to protect as many people as possible. It also calls into question our role as an investor and encourages us to direct our financing towards a low-carbon economy.

We have decided to turn this major challenge into an opportunity. That is why we are mobilising experts and researchers to help the insurance industry move towards new technical solutions. This green book is the first step in this direction.

The DIALog[1] Chair of Excellence team draws on the multi-disciplinary expertise of pioneering climate experts to quantify the impact of climate risk on insurance, particularly in the health and life sectors, CNP Assurances' traditional business.

I have confidence in the expertise and creativity of the CNP Assurances teams, and in the mobilisation of market players to make use of these ideas, which are driving forward the science of climate change.

Marie-Aude Thépaut, CNP Assurances General Manager

[1]Digital insurance and long term risk

Climate Risk and its Impact on Insurance




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1. Objective

This green book presents an introduction for beginners to climate science from an insurance perspective. It is aimed at insurance professionals that know statistical methods, but are new to climate issues. How is climate risk measured? What is its impact on the insurance industry, both for policy-holders and their insurers?

The manuscript is the result of collaborative research work carried out by the DIALog Research Chair. This Chair explores the impact of climate change in insurance. The focus is more specifically on heath and life insurance. The DIALog team regroups members from industry and academia. Several are actuaries : experts in measuring and managing risks.

The consequences of climate change are deep. They are far-reaching, particularly in sectors such as agricultural insurance, property-casualty, health and life insurance. As a result, it can present a threat to the sustainability of insurance programs, in several different ways.

1. **Climate change increases total losses that may require hikes in premiums and in solvency capital**. A precise quantitative assessment of this increase has not yet been determined, but it is clear that both recent and future costs are a serious threat. [16] forecasts increased frequency and severity of events due to climate change that will cost 30%-63% more in insured catastrophe losses by 2040. This cost increase could even reach 90%-120% in specific markets, such as China, the UK, France and Germany.

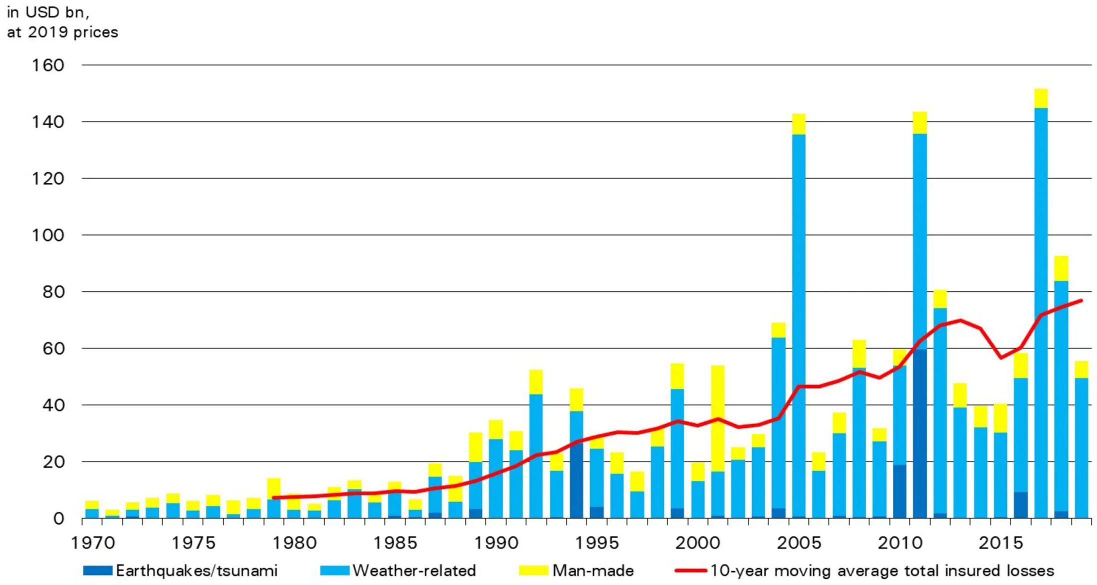

Figure 1: Catastrophe-related global insured losses.

Source: `https://www.swissre.com/media/press-release/nr-20191219-global-catastrophes-estimate.html`.

2. **Climate change puts into question some fundamental principles of insurance**. Such as risk insurability, pooling, diversification, and risk transfer. Optimistic perspectives suggest that far from being adversely affected by climate change the **insurance business could find in it an opportunity**, through the development of new technical solutions [12, 13, 17]

.

The book starts by exploring the need for a standardized method to measure climate change. First, we review the recent scientific literature on the few actuarial climate indices that have been defined so far and **we extend the exist-**

ing methodology to calculate an actuarial index for climate data in France. Then, the next chapter, describes **how climate science can be used to link the physical climate risk to insurance costs**. In particular it focuses on the impact of heat waves on excess mortality. Finally we further **explore the link between extreme temperatures and excess mortality in France**.

Overview of the green book *Climate Risk and its Impact on Insurance*

- **Chapter 1** : Climate risk and actuarial science
  - Section 1 : Climate risk
  - Section 2 : Actuarial climatic indices

- **Chapter 2** : Heat waves and mortality
  - Section 1 : Heat waves and health
  - Section 2 : Building a model
  - Section 3 : Future heat projection

- **Chapter 3** : Climate change and longevity
  - Section 1 : Longevity models, a brief literature review
  - Section 2 : Relationship between temperature and mortality
  - Section 3 : A new model
  - Section 4 : Forecasting mortality rates with the new par notre modèle

2. An actuarial tool to monitor climate change

The atmosphere is a chaotic system, meaning that small differences in the current state can grow into substantial differences over a short term. It is therefore essential to gain reliable knowledge of the current state of the system to make accurate future predictions.

Climate change refers to long-term variations in temperature, precipitation patterns, sea levels, and other aspects of Earth's climatic system. According to the Intergovernmental Panel on Climate Change (IPCC), the observed global surface temperature from 2011 to 2020 was 1,1°C higher than the average in the last half of the 19th century, with land surface temperature increasing by 1,59°C; see [6]. For insurance companies, **any increase in extreme weather events can cause significant damages and result in higher insurance claims**, irrespective of the business line considered (P&C, Health or Life). Moreover, **if historical data are no longer representative due to changing weather patterns, insurers need to reassess the risk models they use** and incorporate climate change projections.

2.1. Definition of a French actuarial climate index

In order to help insurance companies predict and manage climate risks, actuarial climate indices have been defined that combine information from several important variables from historical records. Just as the Consumer Price Index (CPI) tracks changes in the cost of a standard basket of goods and services over time, these actuarial climate indices measure climate risks through a basket of extreme climate events and changes in the sea level. **Those indices focus on extreme weather events rather than averages**; extremes have a greater impact on policyholders and their insured goods, as well as on society and the economy. They consist of several components, each forming a monthly time series (starting in 1961 in our case), from records of the National Oceanic and Atmospheric Administration [NOAA, 9], GHCNDEX1 [CLIMDEX, 4], and from [11].

The actuarial climate indices are calibrated to average to 0 over some given reference period. In all the countries where such indices have been defined, their recent seasonal values are almost exclusively above average. Moreover, **their 5-year moving average has systematically increased since the year 2000**. [5] defines the French Actuarial Climate Index (FACI), using data from the ERA5-Land reanalysis data-set [2] and tide gauge data from the [11]. Figure 2 illustrates the FACI evolution from 1961 to 2022.

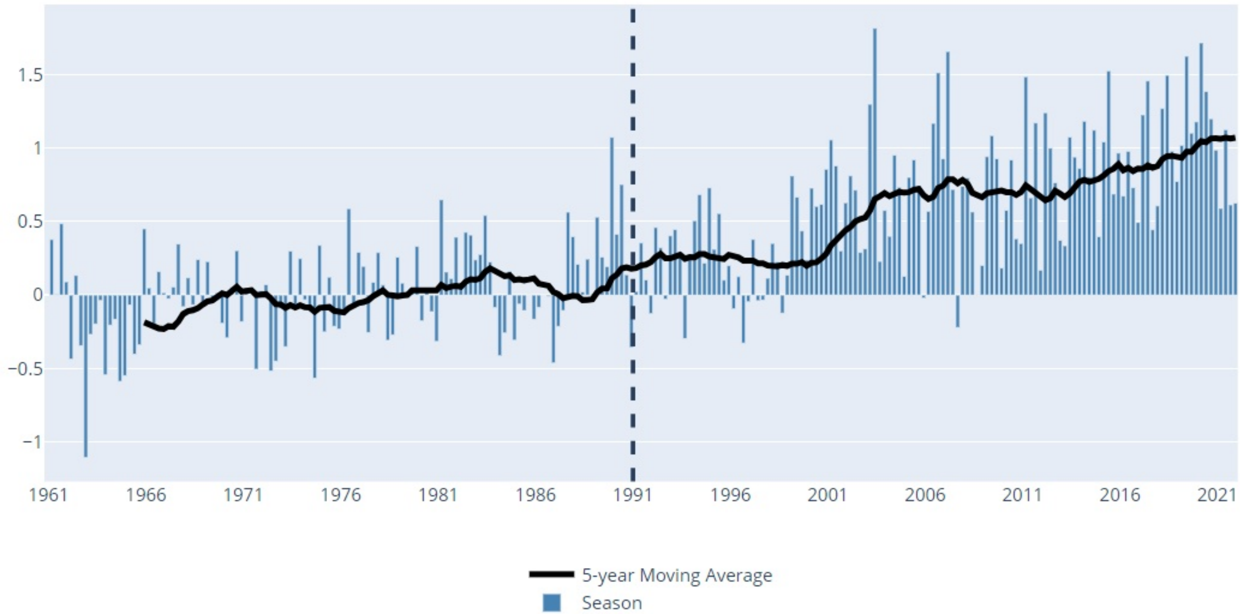

Figure 2: Quarterly FACI values; 1961-1990 reference period to 2022. Source: [5].

The FACI combines six components capturing the information about :

- **high and low temperatures,**
- **precipitations,**
- **droughts,**
- **wind speed,**
- **sea levels**

.

Each comoponent of FACI forms a monthly tume series. All calculations are performed at each individual grid cell level. Then aggregated at the regional level, for all of France and Corsica, component by component. **The ERA5–Land reanalysis data has a high–resolution**, set at 0.1° x 0.1° degrees of latitude and longitude, about 122 km^2, resulting in more than 10.000 grid cells to cover France and Corsica.

2.2. The change in sea levels is the dominant component in France

Figure 3 combines the graphs of the 5-year moving averages of the seasonal FACI and its 6 components. The same illustrations are available in the full version of the green book for the four other countries where actuarial climate indices have been published: the USA, Canada, Portugal and Spain. However, for conciseness, we only provide here the graphs for France.

- The first observation is that the sea level change is dominant. Other countries show similar increasing trends and onset times, around the mid-90's. It is important to recall that ocean and sea level changes depend on the region, within these countries.

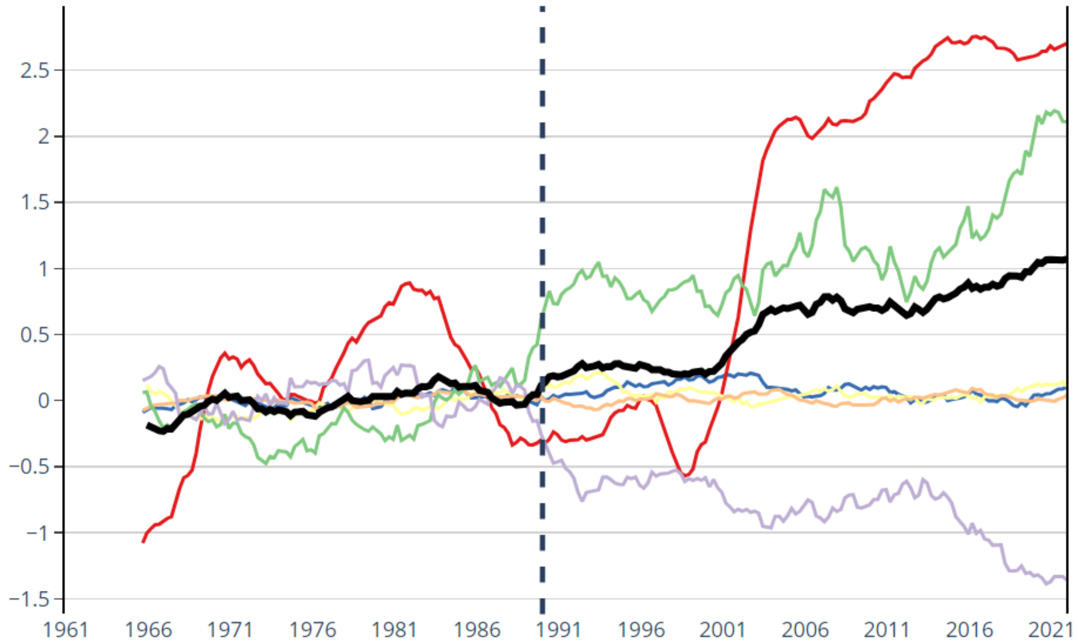

Figure 3: Seasonal 5–year moving averages of components used in the FACI (green: $T90_{std}$, purple: $T10_{std}$, orange: P_{std}, yellow: D_{std}, blue: W_{std}, red: S_{std}, black: FACI). Source: [5].

- The second dominant change, for every country, is for the temperature highs (green curve). Their standardized anomalies are currently highest in France, at around 2.5 in value, and similar in the other countries, at values between 1 and 2. As already noted, the low temperature component ($T10_{std}$) exhibits essentially a mirror image trend to that of $T90_{std}$, but over negative values. That is, both contribute significantly to their respective composite indices increasing trends.

- The findings are quite different for the remaining three components, with no clear trends. In brief, we can conclude that **the increases in these indices are essentially due to the sea level, plus the high and low temperature components**

.

The contribution of each component of the actuarial climate indices differs depending on the country, due to the distinct geography. Nonetheless, their composite indices show a similar increasing trend. Moreover, the index values are themselves similar, ranging from -0.5 to 1.5. This indicates that climate change has led to a similar increase, as a multiple of the standard deviation. And that, both in the frequency and severity of extreme weather events, in France, the Iberian Peninsula or the US and Canada, as compared to the 1961-1990 reference period. **In summary, the occurrence of extreme climate events is becoming increasingly common, overall, in all these regions**.

2.3. What impact on the sustainability of insurance activites ?

How these indices can help quantify the impact of climate change on the balance sheets of insurance companies and, therefore, its impact on the sustainability of the insurance business? For example, [7] uses regression to link the occurrence of heat waves to deaths from heat disorders in Korea. Similarly, using US data, [10] shows that weather events related to climate change significantly contribute to property damages, which in turn impact on mortality rates. On the same theme, [3] finds strong correlations between excess mortality and the 95-percentile of temperature highs, for most regions of Spain. One technique used commonly by actuaries to predict future mortality improvements is the so–called Lee–Carter model, [see 8]. In a series of papers, the method has been extended to include explanatory terms, including one based on a heat index [see 14, 15]. These successfully link the physical climate risk, through the index, to the mortality risk predictions. For additional literature on the impact of climate change on health and life insurance (see [1] and Chapter 3 of the green book, plus the references therein).

Finally, for references on the application of climate indices to non–life insurance see, for example:

[5]: details the design and pricing of a parametric insurance product based on the French Actuarial Climate Index.

[18]: is a recent survey paper that list several other studies linking, climate risk, indices and losses, both in life and Property & Casualty insurance.

3. Heat wave and mortality

Prolonged exposure to heat has been shown to adversely impact health and increase mortality, especially among older adults. This impact has been particularly worrisome during heat waves in the 21st century, like the 2003 European heat wave, when significant spikes in mortality occurred during extreme heat events. Despite the well documented links between heat and excess mortality, **predicting mortality from heat remains a challenge**, due to factors such as:

- limited availability of mortality data,
- the vulnerability dependence on location and age,
- the different environmental factors contributing to heat impact.

Using data from France, we show nonetheless that it is possible to build data driven models to predict the number of summer-time deaths as a function of a heat index. Both statistical and deterministic approaches suggest that **a simple convex relationship exists between the heat index (combining temperature and humidity) and the number of deaths**. However, some caveats remain:

1. In particular, we show that the quality of the prediction can quickly deteriorate if the population vulnerability to heat changes over time, as illustrated in Figure 4. Therefore, **the selected reference period to estimate model parameters is key**, and **assumptions about the future evolution of this vulnerability to heat are essential**.
2. **A prediction model that works in one region does not necessarily work in other regions** as the vulnerability to heat may differ.
3. The results suggest that location-dependent threshold values for heat exist, above which the number of deaths increases at a much-accelerated rate. This occurs when a particular location attains unprecedented heat levels.

In order to obtain projections of future heat-induced mortality, simulations of the future evolution of heat, and more generally of climate, are necessary. These simulations are performed with Earth-system models that represent different future climate evolution paths, based on scenarios that consider different socio-economic developments. These models are built on well-established physical principles and represent all the necessary variables to calculate heat indicators such as temperature and humidity. Despite inherent uncertainties in these models, **ensemble simulations provide a range of possible outcomes, ensuring robust projections of future heat**, thus allowing to model its impact on mortality.

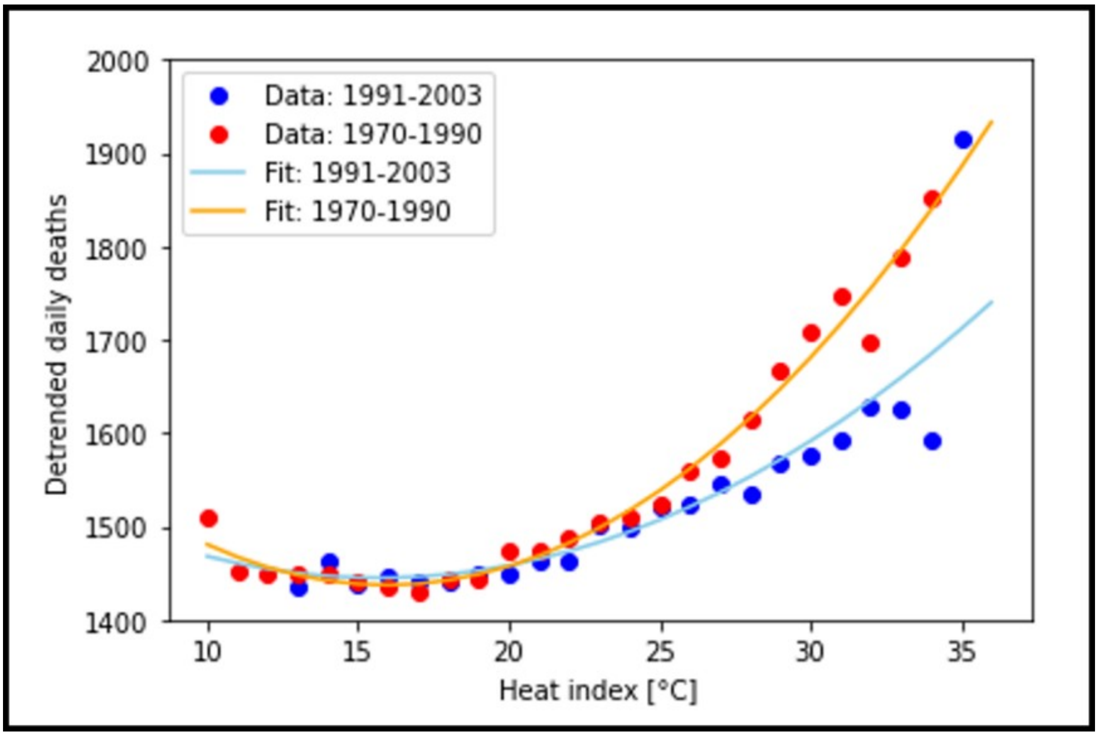

Figure 4: Average detrended number of daily deaths vs average Heat Index (1°C intervals) in France, every day of the summer months (June to August).

4. Mortality forecasts: the need for stochastic models

In recent years, the frequency and intensity of heat waves and cold snaps, and their impact on human mortality, have made climate change a hot topic for the world's major powers. According to recent reports by the World Health Organization (WHO), research shows that **3.6 billion people already live in areas highly susceptible to climate change**, and between 2030 and 2050, climate change is expected to cause approximately **250,000 additional deaths per year**, from under-nutrition, malaria, diarrhea and heat stress alone. The question is whether human beings will adapt to climate change, or whether the impact will continue to grow. The book studies the relation between heat waves and human mortality in France.

1. We first aim to integrate scenarios with strong excess mortality due to unusually hot temperatures (like what happened in France in 2003).

2. Secondly, we try to capture the impact of global warming over mortality rates. To this aim, we develop a stochastic model integrating this relationship in an attempt to predict the impact of heat waves on mortality.

4.1. Our model predicts excess mortality due to high temperatures

Longevity models are statistical tools used to predict future death rates in a given population, **considering the improvement of mortality rates over time** (see Figure 5). They take into account various factors, such as age, gender, health conditions and historical trends, to estimate future probabilities of death at different periods of life. Designed in the early 1990s, **these forecasting mortality models are essential tools for projecting future mortality rates and life expectancy**, providing valuable insights for actuarial, financial, and public health applications. The most popular stochastic longevity model, the Lee-Carter (LC) approach, was firstly proposed by [8]. Before [14], none of these models incorporated an exogenous factor related to global warming in trying to predict mortality trends in the future. Although the latter approach incorporates one term related to temperature, it suffers from crucial issues. In particular, the magnitude of heat waves cannot be taken into account. We believe that measuring to which extent the temperature is hot is crucial to anticipate related excess of mortality. Based on open source databases for mortality and climate, our model, grounded on the LC model, thus integrates this aspect.

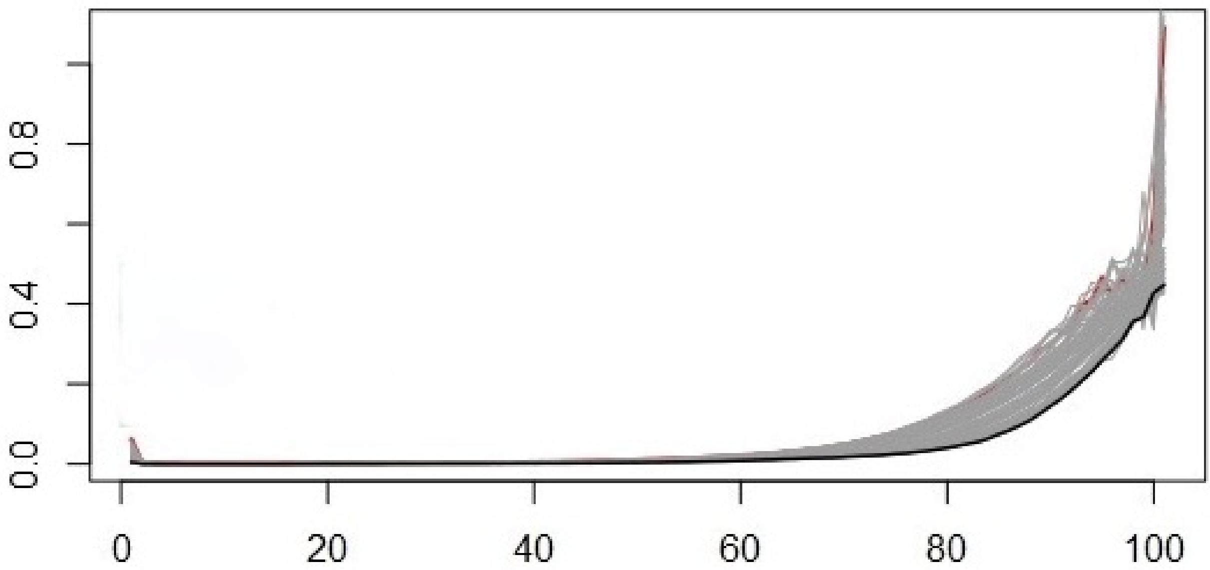

Figure 5: Mortality rate against age: improvement over time (1950: **-**, from 1951 to 2018: -, 2019: **-**).

Abnormally hot temperatures seem to cause more deaths, in particular for elderly people that can suffer from dehydration. In our study, the critical threshold on this concern appears to be 65 years old. We measure the difference between mean summer temperatures for each observed year and mean summer temperature over the whole observed period (more than thirty years, between 1980 and 2011), and integrate this information into the modelling. **To give future projections, it is necessary to consider various climate scenarios that allow to integrate uncertainty** in mortality predictions. Forecasting mortality to future years thus requires forecasting the future temperatures. We use various temperature projections from Météo-France; their website DRIAS Climate Futures[2] provides regionalised projections for France of various climatic factors (temperature, wind, humidity, etc.) based on the different RCP scenarios of the 5^{th} Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Our study shows that **the impact of the RCP scenario is far from being negligible**. As expected, the results suggest that mortality rates will continue to decrease at the same improvement rate for young people (irrespective of gender), but this improvement seems to be **different for older people that are more likely to be impacted by heat waves**.

Finally, the analysis confirms the **importance for insurers and public policies to integrate global warming in their future demographic projections**. Doing so, they can anticipate to some extent the worsening induced by climate change and more specifically heat waves. However, longevity models aim to provide only the global picture. Such models would still underestimate the excess mortality due to unexpected large events, and are thus more useful for risk management than for crisis management. This underscores the **importance of using a scenario-based approach when investigating the future impact of heat on mortality**, especially for solvency purposes.

[2] `https://www.drias-climat.fr/`

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GLOSSARY

IPCC : intergovernmental panel on climate change

FACI : french actuarial climate index

CPI : consumer price index, "a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services."[3]

NOAA : National Oceanic and Atmospheric Administration

RCP : Representative Concentration Pathway

[3] Definition from the Bureau of Labor Statistics

AFTERWORD

In 2023, losses caused by natural disasters worldwide reached 250 billion dollars[4], of which 95 billion dollars were insured. By 2040, a rise from 30 to 63% in insured catastrophe losses is expected [5].

How far can insurers go? And how can they increase their solvency capital without causing policyholder premiums to soar?

In the United States, climate change has already forced insurers to withdraw strategically from certain markets. Will it be necessary to go to such extremes in Europe, and particularly in France?

Climate change is threatening the fundamental principles of insurance, namely the insurability of risks and mutualisation. It is up to us, the insurers and investors in the marketplace, to reinvent them together.

Working together is the future of our industry. Initiatives such as the Fonds Objectif Climat, which was recently renewed and opened up to new institutional investors, and the Fédération des Garanties et Assurances Affinitaires are advancing the understanding of risks and the performance of guarantees. The sharing of knowledge and relevant indicators from the Green and White Papers published by the major French insurers is a step in the same direction.

You can count on CNP Assurances, a player committed to pushing back the boundaries of insurability, a member of France's major public finance group and a beneficiary of the support of Caisse des Dépôts, to work together to advance the science of insurance in France and throughout the world.

Véronique Weill, Chairman of the Board of Directors of CNP Assurances

[4] Munich RE (2024)
[5] Swiss RE (2021)

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