METHODOLOGICAL PAPER

on potential inclusion of climate change in the Nat Cat standard formula

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Introduction

Background and Context

1.1. Due to climate change, the frequency and severity of natural catastrophes is expected to increase. Improved climate projections provide evidence that future climate change will increase climate-related extremes (e.g. heat waves, heavy precipitation, droughts, top wind speeds and storm surges) in many European regions (EEA, 2017 & 2020).

1.2. Climate change could therefore impact all underwriting modules in the standard formula (SF) (Life, Health and Non-life Life).

1.3. In the case of life and health underwriting risk, climate change may impact the sub-modules mortality, longevity, catastrophe and disability/morbidity risk. More extreme weather events, such as heatwaves, could for example lead to higher mortality rates that could result in higher claims in mortality or morbidity portfolios. However, the effect climate change may have on life and health underwriting risks will depend on different factors such as the line of business (LoB). Climate change could also have an effect on the health cat sub-module, especially on the pandemic risk, because it might be possible that diseases which affect only particular parts of the world could also spread in other parts of the world in the future (e.g. malaria, Dengue) (Watts, 2020).

1.4. In the case of non-life underwriting risk climate change may have an impact on the sub-module premium risk. Climate impacts already observed may be priced in the premiums because non-life premiums are generally adapted on an annual basis. Data used by EIOPA for the calibration of the premium risk standard deviation can therefore be assumed to provide a current view of climate change. The non-life catastrophe risk sub-module is one of the central modules to be impacted by climate change. This sub-module consists of three separate and independent submodules dealing with natural catastrophe risk, man-made catastrophe risk and other catastrophe events. The following analysis focuses on the natural catastrophe (Nat Cat) module as climate change could lead to more frequent and severe events that could lead to higher insured losses of non-life insurers.

1.5. The Nat Cat module calculates the Solvency Capital Requirement (SCR) linked with Nat Cat events. EIOPA's Opinion on Sustainability within Solvency II (EIOPA, 2019) highlighted the following points on how climate-related developments were considered in the Nat Cat SCR in Solvency II:

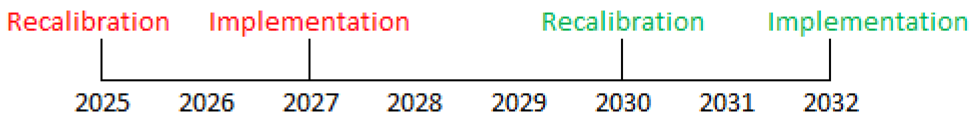
- a regular recalibration of the standard parameters for the Nat Cat risk module of the SF (every 3 to 5 years) should take into account future developments, as well as the potential effect of climate change using the latest data and science available;

- the catastrophe risk modelling community should expand their analyses on the potential effect of climate change and, where material, reflect the results of those analyses into their Nat Cat models;
- where undertakings rely on external catastrophe risk models, they should ensure the model is sufficiently transparent regarding the method and the data used and the assumptions taken in the design of the Nat Cat models;
- further work is needed to investigate whether additional climate change-related perils such as droughts and wildfires could be better captured in the Solvency II framework under the Nat Cat risk sub-module.

1.6. As a follow-up to EIOPA's Opinion on Sustainability within Solvency II, EIOPA will investigate in this paper if and how to include climate change in the Nat Cat SCR calibration in the SF. In order to consider different possibilities to include climate change into the Nat Cat SCR calibration, it is important to note the following aspects:

1.7. Solvency II:

- time horizon: under Solvency II, capital requirements are determined on the basis of a 99.5% value-at-risk measure over one year. For the recalibration process, it is important to note that it can take more than two years between parameters recalibration and when undertakings will actually use these parameters. In addition, the fact that the SF parameters are not recalibrated annually needs to be considered. It is key to ensure that the parameters are adequate for more than one year as the same parameters will be used during multiple years until a recalibration will be done. It might therefore be important to introduce a forward-looking approach when performing a Nat Cat SF parameters recalibration[1] to ensure that the parameters are valid over the next 5-10 years. Let us assume the following example, a recalibration is done in 2025, the next recalibration takes place 5 years later in 2030. However, the industry will implement the parameters from the 2030 calibration only in 2032. This means that the parameters from the 2025 recalibration need to be valid to be used until 2032 (and this under the condition that the new recalibration took place 5 years later);

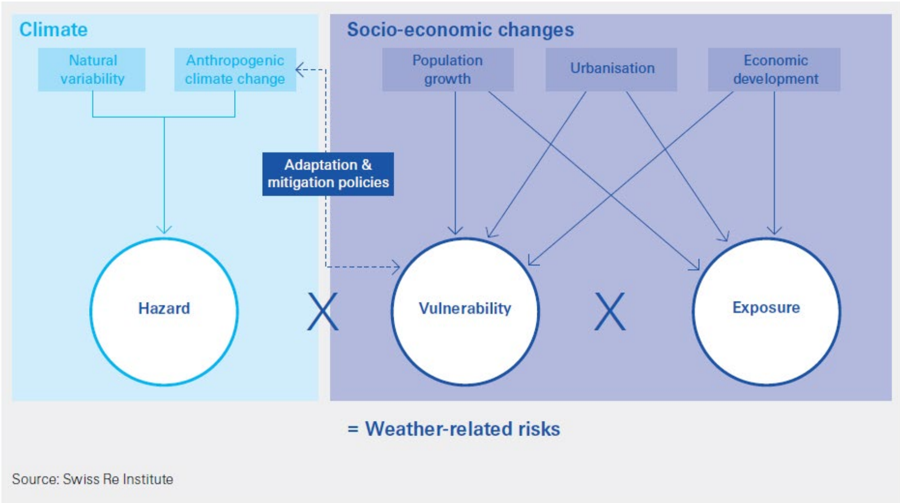


- risk-based: Solvency II is a risk-based approach. It is therefore important to consider all aspects of the risks (for Nat Cat: exposure, vulnerability and hazard). To integrate climate change aspects in Solvency II, it is therefore not sufficient to just consider changes in hazard (for example higher precipitation rates) but it is also necessary to consider the exposure and its

[1] Other risks in Solvency II should (or already do) include a forward looking view.

corresponding vulnerability. If for example flood risk increases, it might well be possible that adaptation measures are taken and flood defences are installed so that the risk does not increase even though the hazard does.

Figure 1: Contributing factors of the three main components of weather-related risks (Swiss Re, 2020).



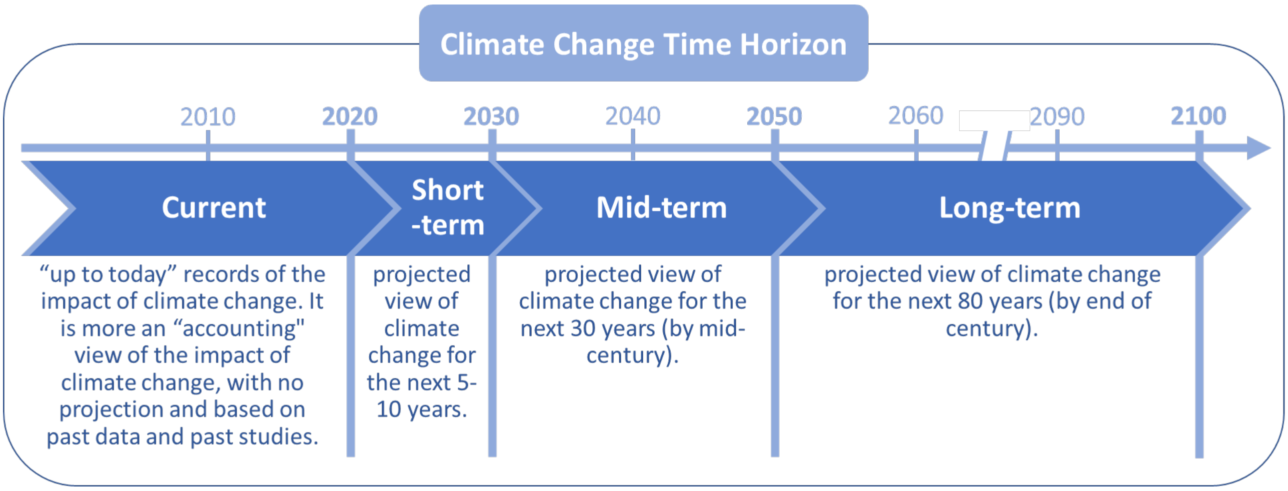
1.8. Nat Cat SCR calibration:

- the current factors are mainly based on output from Nat Cat models. Most Nat Cat models would reflect the Nat Cat risk for the next 12 months. As mentioned in EIOPA's Opinion on Sustainability within Solvency II, the impact of climate change is mostly not explicitly reflected in the current Nat Cat models. Any current climate change shoud be implicitly included in the recent data (historical data) and scientific assumptions used to create the Nat Cat models. Also here, it is important to note that Nat Cat models are not necessarily updated annually as it takes a lot of effort and resources to update a Nat Cat model. The models used in the calibration would therefore typically be a couple of years old;
- since the initial calibration in 2010, one main recalibration took place in 2017/2018 for some country factors and cross-country aggregation matrices (so the 2010 calibrated parameters were used by the undertakings until 2020). The list of perils/countries to be analysed was based on feedback from insurance associations and national supervisors.

1.9. Climate change:

- in order to integrate climate change aspects into the Nat Cat SCR calibration, it is necessary to include new sources of information which were not considered in the calibration until now. For this methodological paper, EIOPA has decided to rely mainly on the information from the European Environment Agency (EEA), the Peseta studies from the Joint Research Center (JRC) and the Intergovernmental Panel on Climate Change (IPCC) report;
- time horizon - from a climate change perspective the following definitions are used in the paper:

Figure 2: Climate Change Time Horizon



1.10. This paper benefited from discussions with EIOPA's Technical Expert Network on Catastrophe Risks[2].

Structure of the paper

1.11. The methodological paper is structured as follows: Chapter 2 discusses the methodology used so far for the Nat Cat SCR calibration. Chapter 3 elaborates on climate change in Europe by analysing which perils/countries are impacted by climate change. Finally, Chapter 4 elaborates on how to include climate change in the Nat Cat SCR calibration in the SF.

Scope

1.12. Within the Solvency II framework, undertakings need to calculate the Nat Cat SCR. Undertakings can choose to use the SF or an internal model if the SF would not properly represent the risk. This paper addresses the Nat Cat module of the SF.

[2] See Section: Organisations which are members of the Technical Expert Network on Catastrophe Risks.

Solvency II Nat Cat SCR
Scope – EEA countries

2.1. The current methodology covers the exposures and perils inside the European Economic Area (EEA)[3] and Switzerland. The SF also includes a calibration methodology for non-EEA Nat Cat hazards, but it is not widely used.

2.2. Indeed, it is assumed that insurance undertakings with material non-EEA exposure will generally use an internal model. In order to verify this assumption EIOPA had a look at the data that is available for floods and windstorms on a quarterly basis. According to this information, non-EEA Nat Cat SCR calculated using the SF represents only 11% of the Nat Cat SCR calculated with the SF for floods and windstorms. Since the exposure is not material it is appropriate that the focus of the SF for this paper is on exposures and perils inside the EEA, UK and Switzerland.

Perils covered in the EEA Nat Cat SCR

2.3. The Solvency II Nat Cat SF covers the following natural perils:
- earthquake;
- flood;
- hail;
- subsidence;
- windstorm.

In order to understand how to include climate change in the SF, it is important to elaborate on what is basically covered by the SF, e.g. the SF includes flood but there might be different types of floods. However, it has to be stressed that it is not the aim to change any definitions of the perils in the Solvency II regulatory framework.[4]

Table 1: Coverage of perils in the SF.

SF Peril name	Type of disaster	SF
Earthquake	Geophysical	Includes ground movement, but neither tsunami nor fire following.
Flood	Hydrological	Includes riverine (or fluvial) floods and floods that result from rainfall (pluvial, or surface water, floods). Storm surge is not included. Flash floods,

[3] The UK is considered in the EEA countries in the SF.
[4] Annex A includes the definitions used in the Emergency Events Database (EM-DAT) as a reference to general definitions of the perils (Centre for Research on the Epidemiology of Disasters – CRED Université catholique de Louvain, Belgium "Emergency Events Database (EM-DAT)", https://www.emdat.be/classification).

		which can be part fluvial and part pluvial, are included.
Windstorm	Meteorological	Includes cyclonic storms (both extra-tropical and tropical cyclones). Storm surge is not a separate peril, but – where material - combined with windstorm due to the inherently coupled nature. Convective storms are not part of the windstorm peril.
Hail	Meteorological	The SF includes in particular hail as the dominant sub-peril, but also other sub-perils of severe convective storms, such as tornadoes and lightning.
Subsidence	Geophysical	Subsidence is part of the SF in France and refers to a swelling or shrinking of clay soils.

2.4. The following table provides an overview of the perils that are covered in the SF due to their materiality in the relevant countries.

Table 2: List of countries and perils that are currently included in the SF[5] (in green).

	Windstorm	Earthquake	Flood	Hail	Subsidence
AT	green	green	green	green	
BE	green	green	green	green	
BG		green	green		
CY		green			
CZ	green	green	green	green	
DE	green	green	green	green	
DK	green				
ES	green			green	
FI	green				
FR	green	green	green	green	green
GR		green			
HR		green			
HU	green	green	green		
IE	green				
IT		green	green	green	
IS	green				
LI	green	green	green	green	
LU	green			green	
MT		green			
NL	green			green	

[5] Note that the table uses the SF peril names.

NO					
PL					
PT					
RO					
SE					
SI					
SK					

2.5. Climate change may affect the natural perils in different ways. Climate change could have an impact on the frequency, severity and regional distribution of windstorms, floods, hail and subsidence. However, a potential impact on earthquake is not so obvious. Therefore, the following analysis does not further consider the latter peril.

2.6. In its paper „The underlying assumptions in the standard formula for the Solvency Capital Requirement calculation” (EIOPA, 2014), EIOPA mentioned that for the calibration especially probabilistic catastrophe risk models were used, but that such models were not available for all the perils and countries in scope. However, the situation has considerably changed in the meantime. Nowadays, probabilistic Nat Cat models are commercially available for all perils and almost all countries covered currently by the SF, except for the following:

- windstorm: Iceland;
- hail: Spain;
- subsidence: France.

2.7. Due to the non-availability of probabilistic catastrophe risk models for many perils and countries in the past and the limitation that several decades of scarce loss experience are not sufficient to calibrate a 1 in 200 year loss level for any peril much of the past calibration was based on expert judgement.

Nat Cat SCR SF parameters

2.8. To calculate the Nat Cat SCR for EEA countries, a number of parameters are used, such as country factors and country & peril correlations (see also EIOPA, 2014). In line with the risk–based approach of Solvency II all parameters consider the hazard, vulnerability and exposure of the corresponding perils/regions.

Definition of Nat Cat parameters used in the SF (EIOPA, 2014)

Country Factors

The country factors represent the per-occurrence 99.5% loss for that peril in the country under consideration, as a ratio of the total sums insured in the country. This can be represented as the one in two hundred years per occurrence PML (Probable Maximum Loss) percentage. For each peril best estimates of each country's 1/200 year per occurrence PML were provided. Expert judgment was used to identify outliers and obtain consensus on the outcome. It was assumed that a peril is not significant for a given country, if *its estimated country factor was less than 1/15 of the largest peril-specific factor for that country.*

Country & Peril Correlations
The matrices for the correlations between perils and between countries were also derived using an iterative discussion process using expert judgment.

Annual Aggregate vs. per Occurrence
The same procedure was used as for the country factors. Estimates of the ratio of the 1 in 200 year annual aggregate loss to the 1/200 year per occurrence loss for each peril were provided. A consensus on how to distribute the 1/200 year aggregate loss between two occurrences for each peril was based on expert judgment.

Zonal Relativities and Correlations
The zonal relativities are proportional to the 1 in 200 year loss of each zone, and the aggregation matrices reflect the correlation between zones at the 1 in 200 year loss level. The calculation and calibration of these relativities were derived using several underlying, stochastic event-based catastrophe risk models and an assumption about the relative distribution between the zones of the total sums insured within the country. While the methodology was consistent, not all countries and perils benefitted from the same level of detailed model treatment. It should be noted that the zonal relativities and correlations only become relevant to the extent that the geographic distribution of an undertaking's exposures deviate from the industry average distribution assumed in the calibration.

Recalibration 2017/2018

2.9. The Nat Cat parameters were initially calibrated in 2010. The country factors for the different perils as well as the country correlations can be found in the Delegated Regulation (2015/35) in Annexes V – VIII (COM, 2014). The materiality threshold used to decide to include or not a specific peril/region in the SF was if its 200 year loss exceeds circa 1/15 of the highest 200 year peril loss. Annex IX carries out the allocation of zones/regions within countries mostly based on postal codes and Annex X sets out the risk weights for each single zone/region for every single country and peril. Annexes XXII – XXVI of the Delegated Regulation set out the correlation matrices of risk factors between the zones/regions within every single country for all perils.

2.10. A recalibration of some of the country factors and cross-country aggregation matrices, as well as some of the country correlations for windstorm and hail took place in 2017-2018. Details on this recalibration (e.g. which specific parameters were recalibrated) can be found in EIOPA's second set of Advice (EIOPA, 2018) and the updated delegated acts (COM, 2019).

2.11. To perform the 2017/2018 recalibration, a work stream composed of external stakeholders (model vendors, (re)insurance undertakings, etc.) and NCAs was set in place. The entire recalibration process took about 2 years.

2.12. The main purpose of the recalibration was to check if the previous calibration was appropriate and to change those parameters where a recalibration was needed based on evidence received and the analysis performed. The recalibration did not consider future climate change.

2.13. The recalibration was performed in the following five steps (for details see Annex B):

a. determination of the list of material perils/regions to recalibrate;

b. determination of the input to the recalibration: Models and industry exposure data;

c. recalibration of the country factors;

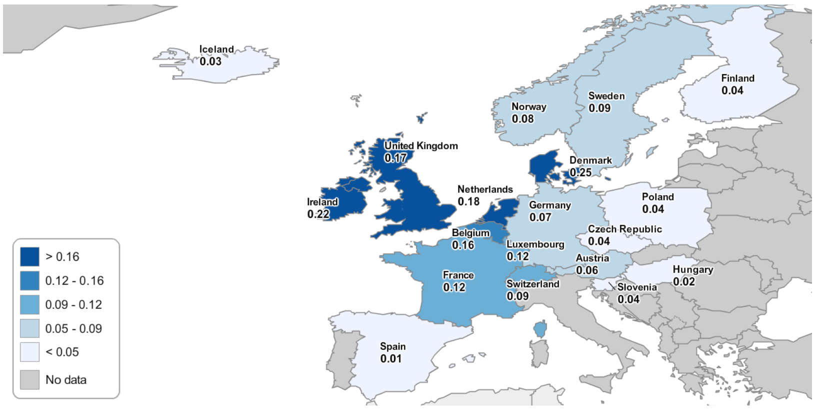
d. decision on recalibration of more granular parameters;

e. recalibration of risk zone weights and aggregation matrices.

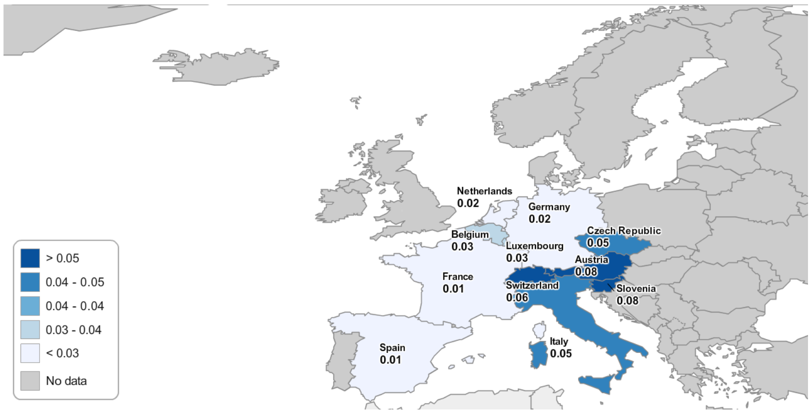
2.14. The following maps provide an overview of the current country factors for the different perils.

Figure 3: Country factors per peril

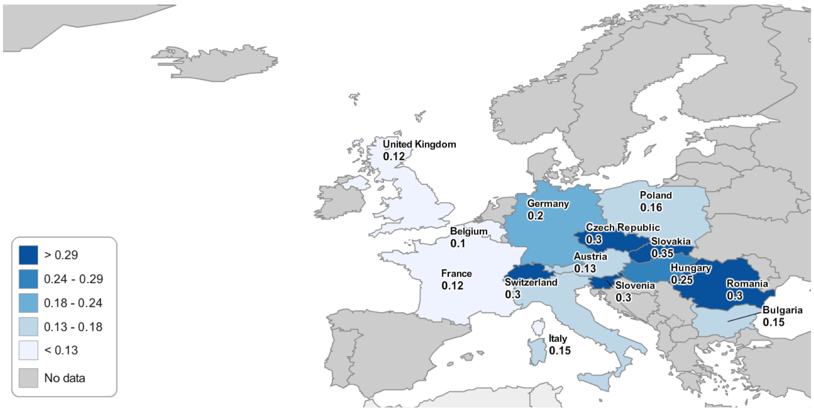
NB: The following country factors include diversification effects within a given country. This leads to the fact that a larger country has a lower factor than a smaller country for the same hazard level.



Windstorm



Hail



Flood

Subsidence

Climate change in Europe

3.1. The European Environment Agency (EEA) reports on climate change, impacts and vulnerability in Europe (EEA, 2017 and 2020) show that climate change is already having wide-ranging consequences for human health, the environment and economies across Europe. In addition, the JRC PESETA IV study stresses the urgent need to mitigate greenhouse gas emissions or adapt to climate change. Limiting global warming to well below 2°C would considerably reduce climate change impacts in Europe. Adaptation to climate change would further minimize unavoidable impacts in a cost-effective manner (JRC, 2020).

3.2. This chapter provides a short summary of the current impact of climate change in Europe as recorded today and presents the projections for the future in the short- to long-term. The perils and countries that are impacted by climate change are summarised based on the last evidence and analysis available. Reference to Annex C is made for a dedicated summary on each of the covered perils. A discussion on the impact of the adaptation measures to the weather-related risk and the importance to take them into account when assessing the risk concludes this chapter.

Overview of the impact of climate change in Europe

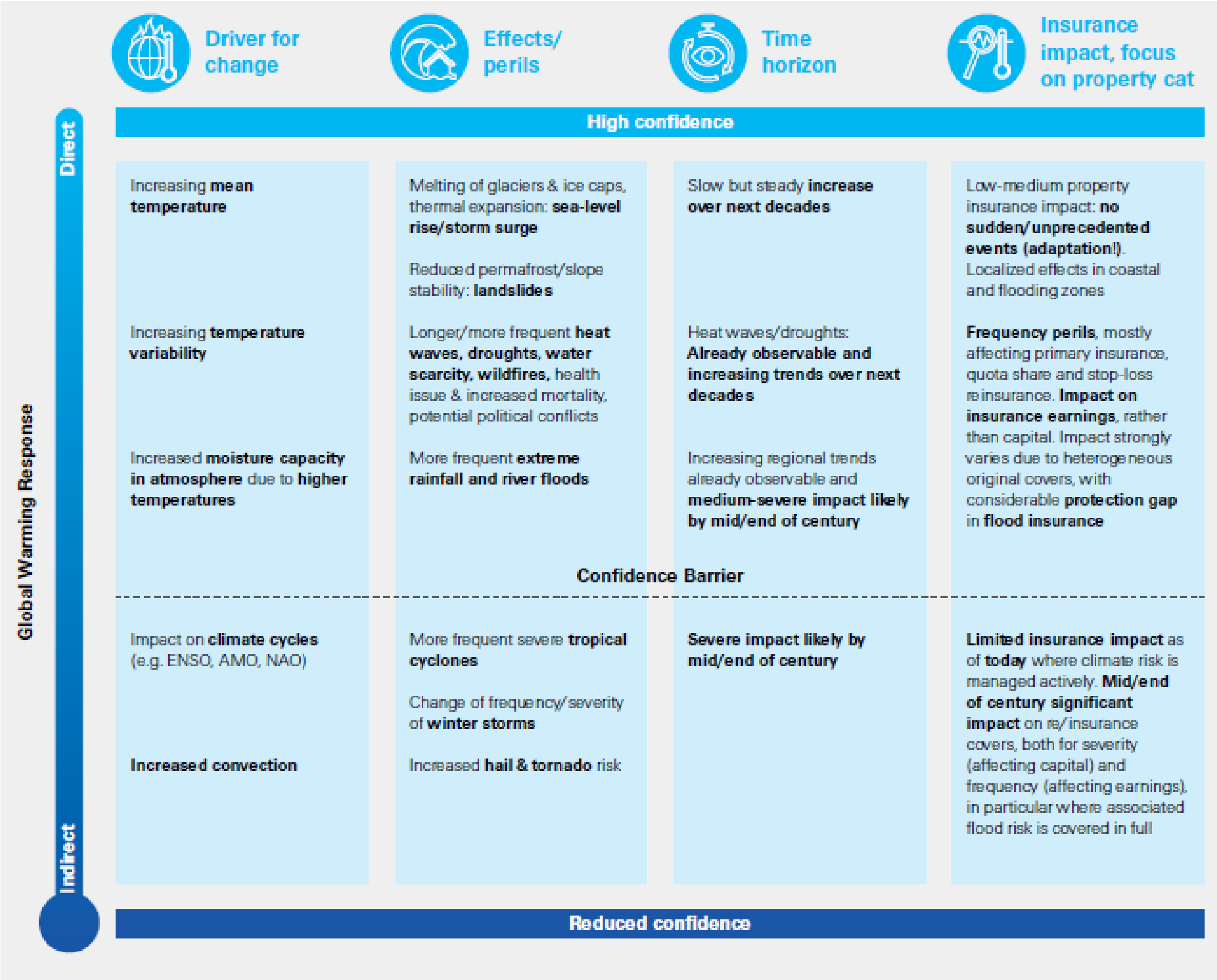
<u>General acceptance by the scientific community</u>

3.3. To develop an understanding about the impact of climate change in Europe, EIOPA focused on the hazards with general acceptance by the scientific community on this question. Swiss Re has assessed the risk in terms of levels of confidence as to expected outcomes across different weather and environmental variables based on available studies and general acceptance of the scientific community. A reduced level of confidence does not imply no impact of climate change but rather that less available data or scientific analysis are presently available (Swiss Re, 2020).

3.4. In Figure 4, weather related risks are classified based on their level of confidence. Confidence about observed and future trends is highest related to increase in global temperatures and temperature extremes.

3.5. More recent developments in science may not yet be reflected in Figure 4. For example, recent studies project climate change to have a substantial impact on severe convective storms (e.g. Rädler et al.,2019). The confidence in a climate change impact on severe convective storms (hail, tornado, thunderstorm gusts) has increased relative to the previous position.

Figure 4: Classification of climate-change effects and their relevance for the re/insurance industry.



Source: Swiss Re Institute

Current and long-term impact of climate change

3.6. As referred in EEA analyses (EEA, 2017 and 2020), climate change is continuing globally including in Europe. Land and sea temperatures are increasing; precipitation patterns are changing, generally making wet regions in Europe wetter, particularly in winter, and dry regions drier, particularly in summer; sea ice extent, glacier volume and snow cover are decreasing; sea levels are rising; and climate-related extremes such as heat waves, heavy precipitation and droughts are increasing in frequency and intensity in many regions.

3.7. New record levels of some climatic variables have been established in recent years, notably global and European temperature in 2019 and 2016, global sea level in 2020 and smallest winter Arctic sea ice maximum extent in 2016. Some climatic changes have accelerated in recent decades, such as global sea level rise and the decline of the polar ice sheets.

3.8. Global climate change has substantially increased the probability of various recent extreme weather and climate events in Europe. The reliability of this finding has been strengthened by recent progress in extreme weather attribution techniques.

3.9. Climate change will continue for many decades to come. Improved climate projections provide further evidence that future climate change will increase climate-related extremes (e.g. heat waves, heavy precipitation, droughts, top wind speeds and storm surges) in many European regions. A summary of the latest projections on the short- to long-term impact of climate change for selected perils is presented in Annex C.

Geographical differences

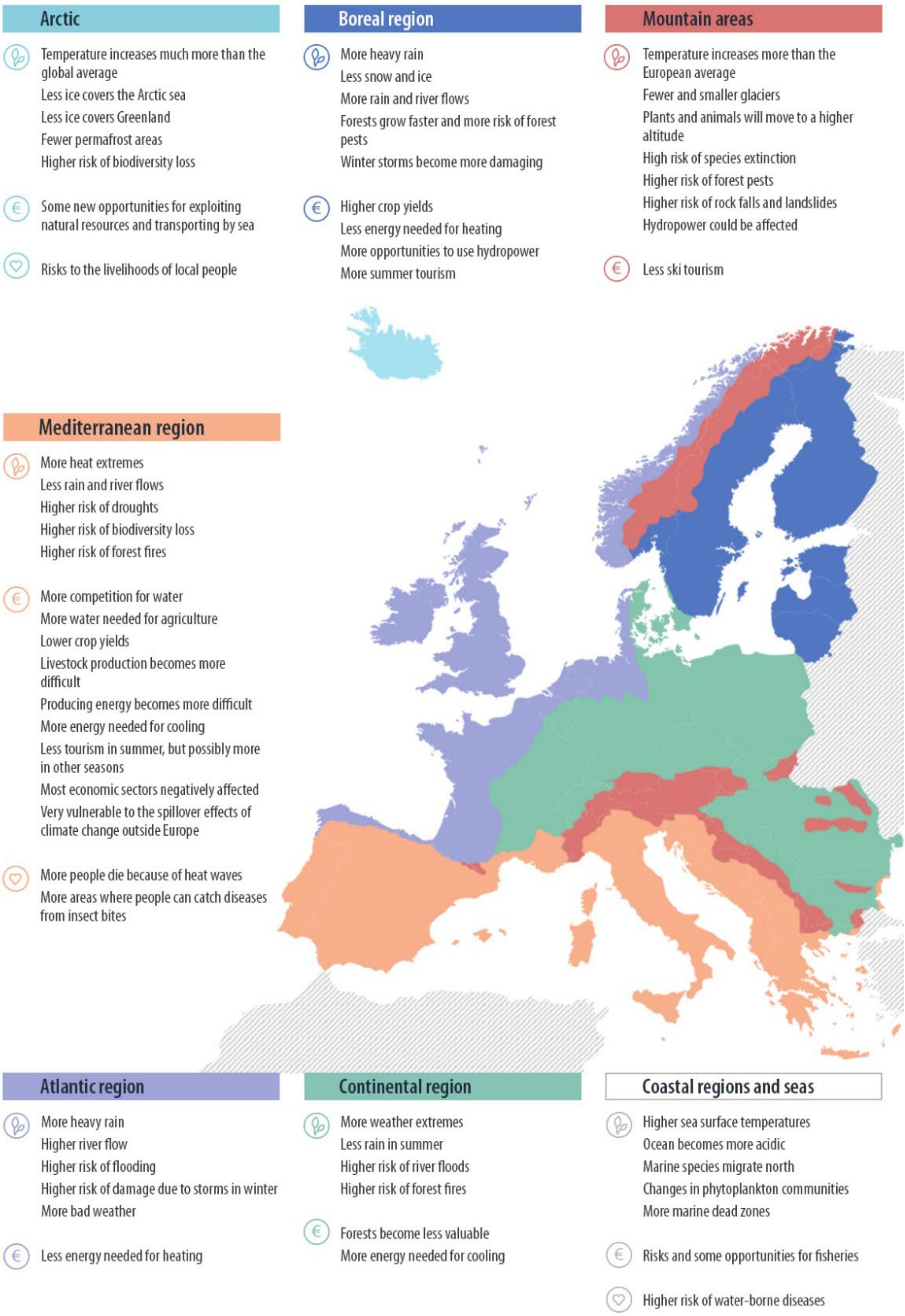
3.10. As shown on the map on Figure 5, different regions and sectors in Europe are or will be affected differently by climate change. The rise in sea level has increased flood risks and contributed to erosion along European coasts. The observed increase in heat waves has had significant effects on human health, in particular in cities. Heat waves are also increasing the risk of electricity blackouts and forest fires.

3.11. Climate change is affecting all regions in Europe, but the impacts are not uniform. South-eastern and southern Europe are projected to be hotspot regions, having the highest numbers of severely affected sectors and domains. Coastal areas and floodplains in the western parts of Europe are also multi-sectoral hotspots. The Alps and the Iberian Peninsula are additional hotspots for ecosystems and their services. Ecosystems and human activities in the Arctic will be strongly affected owing to the particularly fast increase in air and sea temperatures and the associated melting of ice on land, sea ice, and thawing of permafrost both in the Arctic Circle and at high-elevation mountain sites outside the Arctic.

3.12. Economic costs can potentially be high, even for modest levels of climate change, and these costs rise significantly for scenarios of greater levels of warming. The projected damage costs from climate change are highest in southern Europe. However, estimates of the projected economic impacts of climate change in Europe consider only some sectors and show considerable uncertainty.

3.13. The magnitude of future climate change and its impacts from the middle of the century onwards depend on the effectiveness of global climate mitigation efforts. The magnitude of climate change and its impacts can be substantially reduced by keeping the increase in global average temperature well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels.

Figure 5: The impact of Climate change in Europe (EEA, 2017)



Summary of perils and regions most affected by climate change

3.14. The following table summarises the analysis presented in Annex C, highlighting the perils with broad evidence and high confidence of today's impact of climate change and identified the most affected European regions. The table provides a snapshot of the situation based on scientific evidence available at the moment of drafting the paper. Regular updates of the table will be necessary in the future in order to keep it up to date.

3.15. The table also identifies the potential impact of climate change in the short-term (i.e. considering the upcoming period when a new recalibration applies). To do so, the 1.5°C warming projection is taken as reference. In July 2020, climate data from the World Meteorological Organization (WMO) predicts that annual global temperature is likely to be at least 1°C warmer than preindustrial levels (defined as the 1850-1900 average) in each of the coming 5 years (2020-2024) and there is around 20 per cent chance that it will exceed 1.5°C in at least one year (WMO, 2020) in the next 5 years. On March 2021, the Copernicus application 'Global temperature trend monitor' shows that global warming reached an estimate of 1.19°C. The application also shows that if the 30-year warming trend leading up to then continued, global warming would reach 1.5°C by 2034. It is interesting also to notice the estimated timing when global warming would reach 1.5°C is getting closer each year (Copernicus, 2021).

3.16. Mid- to long-term impact of climate change is not included in the table.

Table 3: Summary of the analysis, highlighting the risks with broad evidence and high confidence of the current and short-term impact of climate change and identified the most affected European regions.

Risk	**Current impact of climate change**		**Short-term projection[6]**	
	Evidence of impact	**Most affected regions in Europe**	**Projection of impact**	**Most affected regions in Europe**
Temperature-related				
Wildfire	Yes	Southern, western and central Europe	Yes	Southern, western and central Europe
Wind-related				
Windstorm	No		No	
Water-related				
Heavy precipitation[7]	Yes	Northern and north-eastern Europe	Yes	Scandinavia and northern Europe in winter
River floods	Yes	North-western and parts of central Europe	Yes	Most of Europe except parts of northern Europe and southern Spain
Hail	Plausible in some regions	Alpine countries including northern	Yes	Mediterranean, central and eastern Europe

[6] Impact of climate change under 1,5°C warming projection.
[7] Pluvial flood is included in the SF.

		Italy and Balkan countries		
Drought	Yes	Southern Europe	Yes	Most of Europe, especially southern Europe and except northern Europe
Solid mass-related				
Subsidence	Yes	Soils with substantial fraction of clay (e.g. France)	Yes	Soils with substantial fraction of clay (e.g. France)

3.17. The main sources for the description and analysis are the climate state and impact (CLIM) indicators published by the EEA[8] and the JRC PESETA IV project (JRC, 2020).[9]

Adaptation measures

3.18. As presented in Figure 1, adaptation measures are one of the contributing factors to the components of weather-related risks (Swiss Re, 2020). Adaptation measures can influence the hazard and the vulnerability components of the weather-related risk. It is thus important to take them into account when assessing these risks.

3.19. Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause or taking advantage of opportunities that may arise.

3.20. Examples of adaptation measures include: adapting building codes to future climate conditions and extreme weather events; building flood defences and raising the levels of dykes; developing drought-tolerant crops; choosing tree species and forestry practices less vulnerable to storms and fires.

3.21. According to JRC PESETA IV study, climate change adaptation can reduce unavoidable impacts of climate change in the EU in a cost-efficient way. For example, in case of unmitigated climate change, reducing flood peaks by installing retention reservoirs would reduce annual river flood damage at the end of the century by nearly 40 €billion per year and around 400,000 fewer people would be exposed each year to flooding in the EU and the UK. The annual investment from now until 2100 to install and maintain the reservoirs would be 3.3 €billion/year. There are additional benefits of nature-based storage areas, such as restoring the natural functioning of floodplain areas and improving ecosystem quality (JRC, 2020).

[8] Climate state and impact (CLIM) indicators: https://www.eea.europa.eu/data-and-maps/indicators#c0=30&c12-operator=or&b_start=0&c10=CLIM.

[9] Note that this summary table is built on the information available in the mentioned reports. It is possible that other literatures deviate from the conclusions derived in the chosen reports. Climate change is an evolving science, it is therefore important to consider new developments.

3.22. The effectiveness of past adaptation measures could be assessed through historical data, as for example on wildfire risk. EEA analysis shows that while meteorological fire hazard has increased since 1980 in the Mediterranean region as a result of global climate change, the burnt area has shown a slightly decreasing trend over the same period. These opposite trends suggest that efforts to improve fire management have generally been successful.

Including climate change in the Nat Cat SCR calibration

4.1. Based on the information presented on the current and short-term impact of climate change and the existing requirements for risk-based calibration of Nat Cat underwriting capital charges, this section first elaborates why climate change should be included in the Nat Cat SCR calibration in the SF and then elaborates further on how to include climate change in the Nat Cat SCR calibration in the SF.

Explicit consideration of climate change in the Nat Cat SF calibration

4.2. The current parameters in the Nat Cat SF do not explicitly consider climate change. It could be assumed that to a large extent the current calibration approach captures appropriately climate in the one-year time horizon specified under SII. These parameters are also assumed to sufficiently capture forward-looking trends to be used for a couple more years until a (re)calibration will be performed.

4.3. A number of reasons might support this:

- the current SF calibration uses Nat Cat models which should implicitly reflect the recent climate change;
- the difficulty to quantify future climate change related impacts to catastrophe and extreme weather;
- the amalgamation of climate change with other variables with even more dominance, like urbanization, increased coastal settlements, population growth.

4.4. However, the fact that climate change was not explicitly considered when the current Nat Cat SF parameters were calibrated might be appropriate for certain countries/perils but inadequate for some countries/perils which are experiencing climate change as shown in Part 3 Table 3. A (re)calibration would allow to update the parameters but without specific consideration of climate change impact on the different parameters it will be difficult to ensure that the parameters properly reflect the risk for the time they will be used by the undertakings until a new recalibration will take place (the 2010 Nat Cat parameters were for example used by undertakings to calculate the Nat Cat SCR until 2020). In addition, as climate change is expected to have non-linear effects, an explicit consideration of future climate change in the recalibration is necessary.

Process changes to include climate change in the Nat Cat SCR calibration

<u>Formalise an approach to re-assess current Nat Cat SCR parameters on a regular basis</u>

4.5. In light of climate change, a more structured approach in which all SF parameters are re-assessed on a regular basis needs to be formally defined.

4.6. Every 3 to 5 years experts from NCAs, Nat Cat insurance, Nat Cat modellers and climatologists will reassess the parameters for all perils/regions in the SF and stress the potential need for a recalibration of certain perils/regions. The following criteria could be considered:

- model changes due to climate change or other reasons;
- new scientific evidence on climate change;
- new adaptation measures or new methodogy to take them into account;
- changes in exposure and/or vulnerability;
- materiality of the change;
- new insurance products…

4.7. In addition, the reassessment would also need to consider other parameters such as:

- new legislation;
- evidence-based requests from stakeholders for the recalibration of a certain peril/region;
- changes in national insurance schemes (new pools for example);
- inadequate loss ratio…

which might not directly link to climate change but still have important consequences.

4.8. The outcome produced by such a group of experts will be a list of perils/regions which should be recalibrated and an agreement that the method (models) used to calibrate these parameters are appropriately reflecting climate change.

4.9. Depending on the outcome of this committee, a recalibration could be suggested if necessary. In order to perform its task, a number of data would be necessary:

- information about models on how they capture climate change;
- information about climate change science;
- loss data to identify trends;
- information on vulnerability, exposure changes;
- information on insurance scheme changes in the countries…

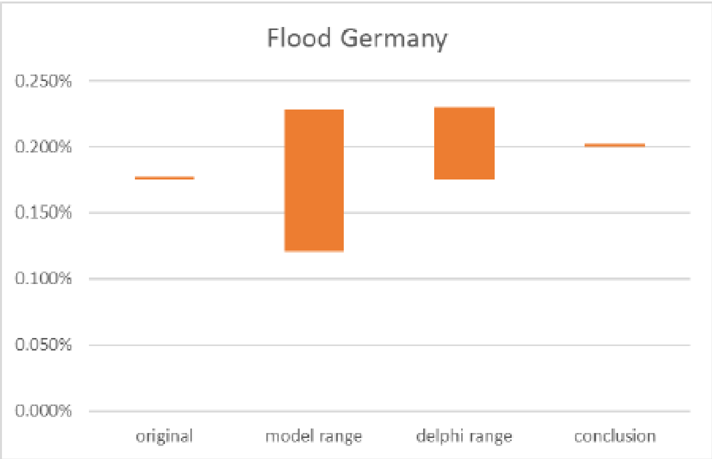
4.10. Formalizing an approach to re-assess current Nat Cat SCR parameters on a regular basis received strong support from stakeholders that participated to the consultation of this paper. Stakeholders noted that climate change was not the only factor influencing the calibration and agreed that adaptation measures should be taken into account in a future calibration, but they noted the challenge of such exercise.

<u>Perform regular recalibrations</u>

4.11. As already mentioned in EIOPA’s Opinion on Sustainability within Solvency II, this approach suggests to perform regular recalibration (every 3 to 5 years) in order to capture latest trends on climate change instead of ad-hoc recalibrations.

4.12. The main reason which supports this option is the fact that by recalibrating the parameters you will include the latest data/models available. However, the high uncertainty around climate extreme events and corresponding losses suggest to be careful with updating too frequently the parameters to avoid capturing the natural high volatility that is intrinsic to low frequency, high severity events. In addition, the inherent uncertainty of the Nat Cat SCR SF calibration is well above the residual impact of climate for a 12 months forward looking view. As shown in Figure 6 "model range", the different models used during the calibration of the natural catastrophe show a high degree of variability in the model outputs. A number of assumptions need to be taken when building a model and these can differ between different model vendors. The expert judgement, which is an intrinsic step in the calibration process, also adds additional uncertainties to the process (see Figure 6 – "Delphi range" and decision on final parameter "Conclusion"). A recalibration should only be performed if there is a clear material signal that the parameters are not appropriate anymore.

Figure 6: Recalibration example for "Flood Germany".



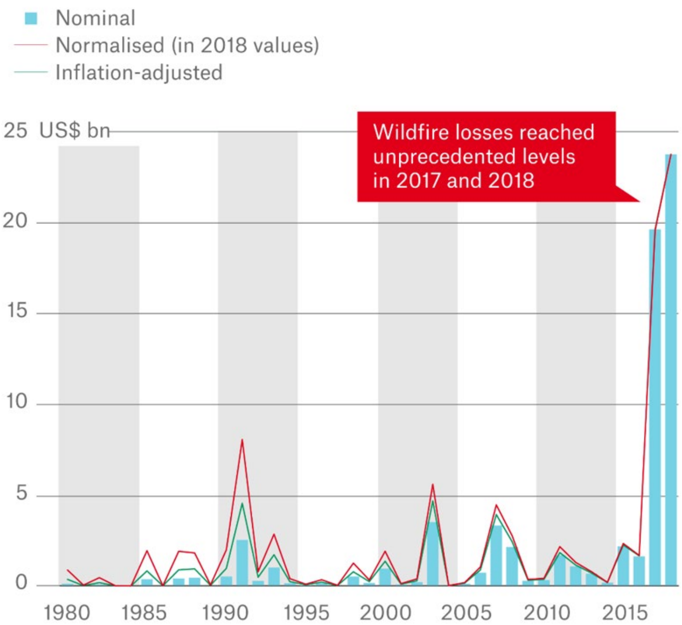
4.13. Stakehoders that participated to the consultation in preparation of this paper were unanimously in favour of a regular recalibration under the condition that the changes are material in order to not include artificial volatility.

Methodological steps to include climate change in the Nat Cat SCR calibration

Use Nat Cat models which explicitly consider climate change

4.14. The impact of climate change is mostly not explicitly reflected in the current Nat Cat models used to perform the calibration of the SF parameters (EIOPA, 2019). Any current climate change should be implicitly included in the recent data (historical data about the events or the losses) used to create the Nat Cat models. However, it is also worth noticing that Nat Cat events are quite rare, many years of historical data are needed for calibrating – but only very few years of the current climate change are included in the historical data. This might be sufficient for certain perils/regions where past trends can still be assumed to reflect the short-term climate change time horizon. However for certain perils strongly impacted by climate change it will be important to consider a more forward-looking approach to not base the risk estimation only on historical data or scientific data which do not consider a projection approach of the hazard[10]. An example, which illustrates very well the issue in light of climate change of relying only on historical data, is wildfire California (Figure 7). Indeed, if the historical losses are used to calibrate the model, then the estimated risk might be underestimated as due to climate change the **wildfire risk in California has increased (MunichRe, 2019). In 2019, the insured losses** were equal to US$ 0.94 bn. In 2020, the losses will again be much more substantial than the historical average[11]. To model properly wildfire risk in California, it is necessary to explicitly account for climate change aspects.

Figure 7: Overall losses – California wildfire (MunichRe, 2019).



4.15. Climate change means the assumption that past losses are a reliable way to estimate future losses may no longer hold true. In this situation, it becomes even more important to adopt modelling based scientific principles to assess the risks. However, incorporating climate change impacts into Nat Cat models is very challenging for a number of reasons (Dlugolecki et al., 2009):

- differences between the temporal and geographical scales on which climate change is considered and those at which the insurance industry operates. Insurance might look at estimating risks for the next 12 months. However, most climate change research consider long-term time horizon. Global climate models (GCM) operate usually on a fairly coarse grid (prediction points typically a few hundred kilometres apart). The insurer considers risks at a particular property level;
- differences between GCMs;

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[10] Note that as mentioned in section 4.3, the ability to model climate change explicitly is not the only consideration that should go into selecting a model.
[11] https://www.reinsurancene.ws/2020-already-third-highest-year-for-insured-cali-wildfire-losses-moodys/.

- natural variability in the weather, which makes it difficult to trend.

4.16. In light of climate change, there is a clear need to ensure that model vendors and insurers collaborate with academic and scientific communities to develop a better understanding of the uncertainties involved in climate change and how these impacts can be quantified.

How could such an approach be implemented in the SF?:

4.17. Consider if for certain perils/regions strongly impacted by climate change as shown in Part 3, Nat Cat models explicitly considering climate change can be used. Climate change sensitivity analysis using today's Nat Cat models is also another tool to be considered.

4.18. For instance, as mentioned in EIOPA's sensitivity analysis of climate-change related transition risks (2020), a recent study sheds some light on the likely magnitude of changes in flood risk for the European insurance sector (RMS, 2020).

Box 1: Modeling Future European flood Risk (RMS, 2020).

RMS used the EURO-CORDEX[12] simulated changes in daily maximum rainfall (as provided by CMCC)[13] to adjust their riverine and pluvial-flood model in order to estimate the expected changes in losses for (re)insurance undertakings under RCP scenarios and time horizons.

The results presented in the paper show that the impact of climate change on precipitation patterns could significantly increase flood risk across Europe over the coming decades:

Average annual losses across Europe are projected to increase by 34% to 75% in 2050, depending on which future pathway of greenhouse gas emissions is assumed.

Regional results show that the impact of climate change on future losses is particularly significant in north-western Europe, including France and Germany, whereas southern countries such as Italy and Hungary are experiencing comparatively smaller changes.

4.19. A number of model vendors have also very recently published new sets of models which include climate change and allow for physical risk modelling. These new models will also be considered in future calibrations.

4.20. Another possibility is to explore other types of models such as the one available on OASIS[14] (platform which hosts models from many different providers) for

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[12] In line with a similar study on future precipitation patterns in Europe, EURO-CORDEX results project an increase in extreme rainfall most of the year in Northern and Central Europe. For further details, please see: https://euro-cordex.net/index.php.en.https://euro-cordex.net/index.php.en.

[13] Changes in 95th percentile of daily maximum rainfall expected under the RCP4.5 scenario for 2041-2070 period (relative to the base period 1981-2010).

[14] https://oasislmf.org/.

example which would aim to explicitly consider climate change (see for example Hattermann et al, 2018).

4.21. In addition, to consider climate change and for the calibration in general, it might be important to bring more transparency in the model used. EIOPA could explore the use of "open source" models. In the US for example, Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, hurricanes, and tsunamis[15]. There are other open source models such as CLIMADA[16], which provides an open and independent view on physical risk.For example, for European winter wind storm risk, an ensemble of EUROCORDEX regional climate models is used to predict regional changes to storm intensity and extreme wind speed. In order to incorporate climate change impacts, CLIMADA's synthetic storm hazard set in accordance with projections on extreme winds from EUROCORDEX regional climate models[17] (See Box 2 - ClimateWise, 2019).

4.22. Model providers should be able to state if/how climate change is considered in their model and for what time frame their model results are valid. Expert judgement will still be necessary to reconcile the different model results – including those with and without explicit treatment of climate change. Additional climate models for long-term assessments complement traditional models.

Box 2: Incorporating climate change impacts in CLIMADA's synthetic storm hazard set (ClimateWise, 2019).

Following the methodology provided in Donat et al. (2011), the outputs from EUROCORDEX were used to estimate how the 99th percentile maximum daily wind speed during the months of October to March changes between present day and future climate change scenarios. For each individual member of the EUROCORDEX ensemble the 99th percentile maximum daily wind speed was calculated during the months of October to March at each 12.5km grid cell for the time period 2000–15, which is taken to represent present day conditions. The procedure was repeated for RCP4.5 and RCP8.5 emissions scenarios over the period 2045–55, as proxies for 2°C and 4°C scenarios. For each grid cell location and each ensemble member, the 99th percentile daily maximum wind speed under future scenarios was substracted from the present estimate. Finally, all models were averaged, resulting in a prediction of the change in extreme wind speed for each grid cell. By interpolating the EUROCORDEX grid to that of WISC[18], this spatially explicit adjustment was applied to each of the synthetic storm footprints generated by CLIMADA. Although this methodology does not explicitly model the frequency of storms, it increases the frequency of more extreme storms by shifting the entire distribution of wind speeds.

[15] https://msc.fema.gov/portal/resources/hazus.
[16] https://wcr.ethz.ch/research/climada.html (other models might also exist which could be further considered in the future).
[17] EUROCORDEX is a high-resolution regional climate change ensemble for Europe, providing outputs from a number of regionally downscaled climate models on a large number of climatic variables.
[18] https://climate.copernicus.eu/windstorm-information-service?q=wisc-windstorm-information-service.

Assessment of including new countries

4.23. Another way to ensure the SF properly covers the risk in regions affected by climate change is to assess whether new countries should be added to the countries currently covered by the SF.

4.24. The reasons for considering this approach is that due to climate change, the frequency and intensity of certain perils in certain countries might change. Countries which might not have been relevant for the (re)insurance sector in the past might become more relevant. This would need to be captured in the SF. Of course in order to be included in the SF, the new country should pass the materiality threshold.

4.25. However, the observation that climate change impacts a country/peril combination does not automatically necessitate the inclusion in the SF. Not only should the hazard increase but also the associated risk. For instance, due to adaptation measures the hazard risk might increase significantly without a commensurate increase of the insurance risk. In addition, where insurance penetration is low and is expected to remain low, a country/peril combination may be considered not material enough for the insurance sector to justify its inclusion in the SF.

4.26. How could it be implemented?: Considering the perils/countries currently covered in the SF, EIOPA identified the following countries, which could be added based on the analysis made in Part 3 in this paper. The perils earthquake and windstorm have not been considered. As mentioned in Part 2, EIOPA does not expect climate change to have a direct impact on earthquakes and as mentioned in Part 3 there is no consensus on how climate change impacts windstorm risk. The table below shows whether additional countries could be material for the insurance sector to be added to the SF (yellow means could be material).

Table 4: New countries which could be considered in the SF.

	Windstorm	Earthquake	Flood	Hail	Subsidence
AT					
BE					
BG					
CY					
CZ					
DE					
DK					
ES					
FI					
FR					
GR					
HR					
HU					
IE					
IT					
IS					
LI					

LU					
MT					
NL					
NO					
PL					
PT					
RO					
SE					
SI					
SK					

Estimated materiality for the new regions for the insurance sector (yellow = could be material)

4.27. Analysis for subsidence: The data from the Risk Data Hub shown in Part 3 suggests that other countries such as Germany, Italy or Spain could also have subsidence risk (see Annex C: part subsidence). However, this risk seems to not be relevant in Spain as in many regions in Spain everything gets wet and everything dries several times a year (not like in France, which only dries in severe droughts every several years), these areas are easily identified as unreliable and do not build on them. From an insurance standpoint, subsidence is neither material in Italy nor Germany. Also no model is available to make proper assessment of the risk of subsidence in additional countries. EIOPA will therefore add subsidence and how it is impacted by climate change as a peril to be monitored (see section below).

4.28. Analysis for hail: The summary table in Part 3 suggests that regions most affected by hail in light of climate change could be Mediterranean, central and Eastern Europe regions. In addition, countries in the northern part of Europe such as Finland and Norway, which have not be considered so far in the SF could also be material enough to be included as new models are now available for hail. Using cat models first estimations:

- Poland could be material as the expected losses are estimated to be of the same magnitude as ETC losses which is already considered in the SF;
- Finland could be material as the losses are estimated to be half of the losses from ETC which is considered in the SF;
- Norway could also be material as the losses are estimated to be ~20% of the losses from ETC which is considered in the SF;
- Hungary has a lower probability to be material as the losses are estimated to be ~20% of the EQ loss cost, which is not the dominant peril (flood is the dominant peril);
- Bulgaria: no analysis was performed for Bulgaria as no model was available.

4.29. Analysis for flood: Based on the analysis in Part 3, river flooding could be impacted by climate change in most of Europe. For river flooding, countries such as Croatia, Ireland, Denmark or Sweden could be considered to be included in the SF. Pluvial flooding could be impacted by climate change in northern and north-eastern Europe. Countries such as Denmark, the Netherlands and Sweden could be impacted by more pluvial flooding. Denmark is already exposed to pluvial flood (large event in 2011 caused an insured loss of around € 800 million). In the Netherlands the insurance penetration is relatively low for the coastal and fluvial flood so the materiality for the insurance sector would also be low. Pluvial flood however is covered in the Netherlands. An event like the Copenhagen Cloudburst in 2011 could also happen in the Netherlands. For motor, all types of flood are covered. The insured loss for motor can cost a few hundred millions in a 1 in 200 year event. Flood risk in Ireland is increasingly prevalent and should be considered in any future recalibration exercises. From a model estimation, LU could also be sufficiently material to be included in the SF.

Figure 8: Insured losses for hydrological events[19] NATCAT Service MunichRe[20] (2018 USD values - millions)

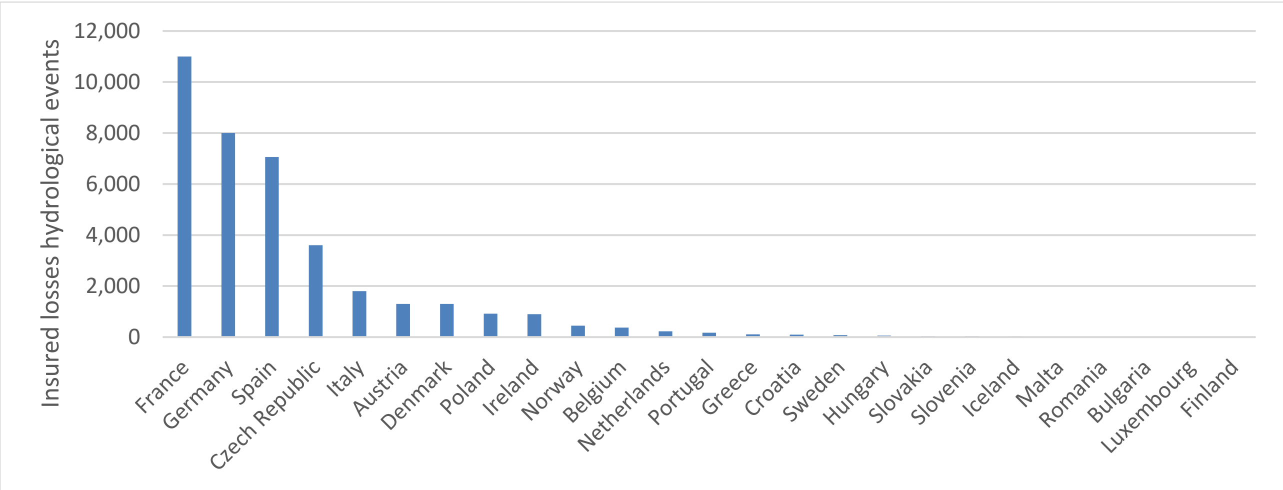
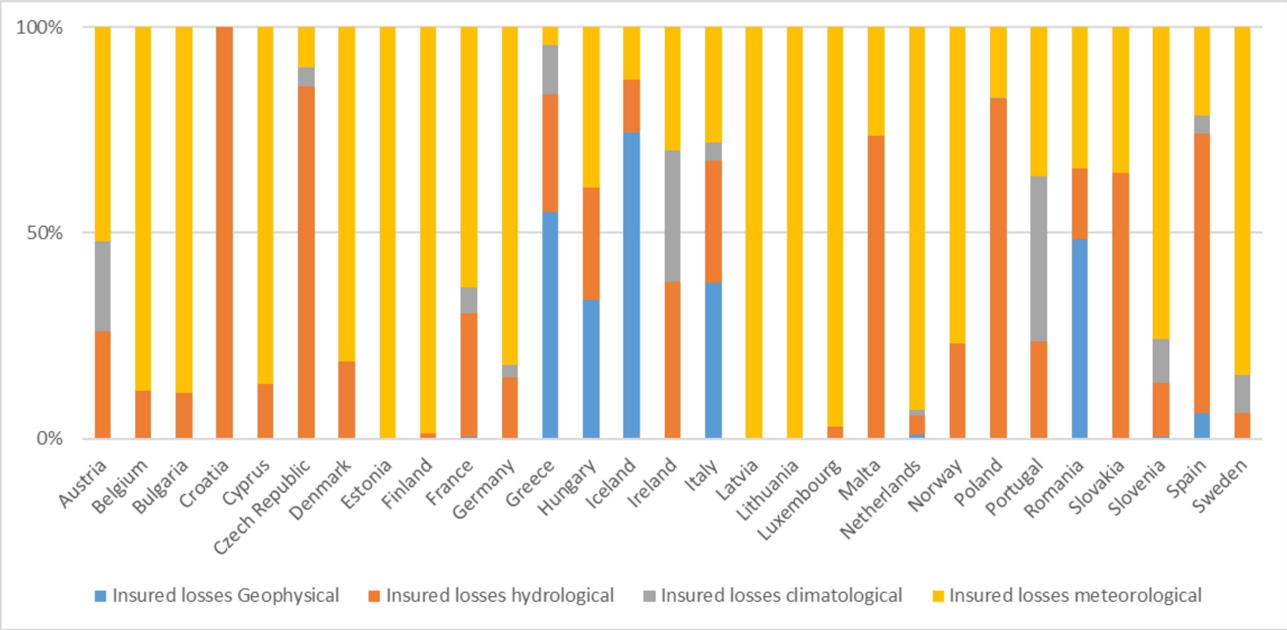


Figure 9: Relative percentage of historical insured losses for geophysical, meteorological, climatological and hydrological events[21] per country (Source: NatCatService MunichRe as of June 2018).

[19] Note that hydrological historical events capture more than just river floods.
[20] NatCatService data from MunichRe were taken from MunichRe's website in April 2020.
[21] See definition of meteorological, climatological and hydrological at: Centre for Research on the Epidemiology of Disasters – CRED Université catholique de Louvain, Belgium "Emergency Events Database (EM-DAT)", https://www.emdat.be/classification.



4.30. Coastal Flood: Currently coastal flood is only considered for the UK in the windstorm module. In light of climate change, it might be worth exploring if coastal flood should also be considered for other countries such as Germany and France. As per expert knowledge, coastal flood is not a material risk for the insurance sector in Germany and Italy. Coastal flood risk exists in France but is not considered as a material risk especially since storm Xynthia (2010) led to preventive measures in order to limit the exposure at a non-catastrophic level. However better understanding of coastal flood and how it is impacted by climate change is necessary. EIOPA will therefore add this peril as a peril to be monitored.

Monitoring new emerging perils

4.31. This approach suggests that in light of climate change new perils should be added to the perils currently covered by the SF.

4.32. The reasons for supporting this would be that due to climate change, the frequency and intensity of certain perils might change. Perils which might not have been relevant for the (re)insurance sector in the past might become more relevant. This would need to be captured in the SF.

4.33. However, it will always be necessary to keep in mind that the new perils/countries need to have a material impact to the insurance sector in order to be included in the SF.

4.34. How could it be implemented?: One peril that has been identified in Part 3 has been impacted by climate change and which is currently not included in the SF is wildfire. Countries such as France, Italy, Portugal, Spain and Greece are particularly affected by wildfire.

4.35. In certain countries, wildfire could be material for the insurance sector. In Portugal for example, forest fires of 2017 caused €1bn in damage; €244m covered by insurance. Figure 9 also shows that in the past climatological historical insured losses, which captures wildfire losses, have already shown to be relevant for a number of countries.

4.36. In addition, after anticyclone Hartmut in February, a long, hot and exceptionally dry summer in Sweden and other Scandinavian countries led to major wildfires, causing over $100m of damage to agricultural land and forests, of which $87m was insured. This had an impact on Swedish insurers' property claims, which rose by 9.3% (Insurance Europe, 2018). In light of climate change, it might be necessary to evaluate if wildfire could have a material impact for the SF.

4.37. No wildfire models are currently available for Europe. Indeed, commercial vendors currently model wildfire and bushfire for North America and Australia.

4.38. JRC's EFFIS historical satellite data regarding wildfires in Europe (e.g. hectares burned) could be used to develop such models. However, there is no central or decentralized data source for Europe that collects the number of buildings burned in a wildfire, which is the key metric for insurance.

4.39. EIOPA will monitor the risk of wildfire and the impact on the insurance sector to regularly assess the potential need to include this in the Nat Cat SF.

4.40. In order to monitor the inclusion of new perils such as wildfire, it will be necessary to have access to historical claims to see the trends in economic and insured losses for the different countries. The challenge of doing such monitoring is the difficulty to access some relevant data. Wildfire models will also need to be developed for Europe to better understand and monitor the risk.

4.41. In addition, another peril which could be added in the SF could be droughts. This peril would be particularly relevant for crop insurance. Crop insurance may potentially be material for some insurers. Whilst it may not be material for the entire insurance sector at the moment, it may become material in the future. EIOPA will therefore continue to monitor the impact of crop insurance to regularly assess the potential need to include this in the Nat Cat SF.

Box 3 - Monitoring emerging perils

EIOPA identifies a number of perils which should be monitored in the context of climate change:

- droughts
- wildfire
- subsidence
- coastal floods…

The challenge with emerging risks is that there are not many data, models, knowledge available to monitor these perils.

EIOPA would monitor these perils by:

(1) Monitoring risk in Europe: EIOPA will look for analyses, data available to understand the risk in Europe.

(2) Monitoring historical economic and insured losses: historical data can be very useful to understand the impact of the risk to the entire economy and to the insurance sector.

(3) Understanding the insurance penetration of the private sector in Europe: in order to understand the materiality to the insurance sector, it is also very important to have a good picture about the insurance penetration of these perils and how they are covered in Europe.

(4) Understanding potential future losses: none or few models are available to estimate potential future losses. EIOPA will work in collaboration with the Technical Expert Network on Catastrophe Risks to enhance the understanding of potential future losses.

Conclusions

5.1. The methodological paper discussed the methodology used so far for the Nat Cat SCR calibration and presented perils/countries which are impacted by climate change. Finally, the paper elaborated on how to include climate change in the Nat Cat SCR calibration in the SF.

5.2. There is a clear need to explicitly consider climate change in the Nat Cat SF calibration for peril/regions identified in Part 3 (see Table 3 which summarizes the perils with high confidence of the current and short-term impact of climate change in Europe). The main conclusions from this paper clearly support to formalise an approach to re-assess and, where material, recalibrate Nat Cat SCR parameters on a regular basis.

5.3. These regular re-assessment/recalibration would of course integrate new considerations such as use models which explicitly consider climate change as well as the possibility to include new countries. The paper also identifies the need to enhance the understanding on emerging perils such as wildfire or droughts for example.

5.4. More transparency is an important element for adequate consideration of climate change. Disclosure of the handling of climate change for any model used in this context would be very useful for industry as well as supervisors. Undertakings could use this information to assess possible deviations of risks that are not reflected in the calculation of the SCR. Thus, transparency and expertise will enable undertakings to profoundly reflect risks enhanced by climate change in their risk management and governance, e.g. in the ORSA.

5.5. The use of open source models where possible and appropriate will also help to allow for more transparency and the possibility for firms to better understand the recalibration.

Annex A

Table 5: EM-DAT definitions of perils covered by the SF[22].

SF Peril name	Type of disaster	EM-DAT definition
Earthquake	Geophysical	Sudden movement of a block of the Earth's crust along a geological fault and associated ground shaking.
Flood	Hydrological	General term for the overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than-normal levels along the coast and in lakes or reservoirs (coastal flooding) as well as ponding of water at or near the point where the rain fell (flash floods).
Windstorm	Meteorological	The peril "windstorm"[23] has different categories (cyclonic storms and convective storms): • Extra-tropical cyclones: Type of low-pressure cyclonic system in the middle and high latitudes that primarily gets its energy from the horizontal temperature contrasts in the atmosphere. • Tropical cyclones: Originates over tropical or subtropical waters[24]. • Convective storm: Range of events generated by strong vertical movements in the troposphere, implying fast condensation and release of big amounts of energy. Among its effects are hail, lightning, heavy showers, strong winds and tornadoes.
Hail	Meteorological	Sub-category of convective storms (see definition above).
Subsidence	Geophysical	Refers to the sinking of the ground due to groundwater removal, mining, dissolution of limestone (e.g. karst, sinkholes), extraction of natural gas, and earthquakes.

[22] Centre for Research on the Epidemiology of Disasters – CRED Université catholique de Louvain, Belgium "Emergency Events Database (EM-DAT)", https://www.emdat.be/classification.
[23] For the peril "windstorm" the following definitions partly differ from the definitions of the EM-DAT.
[24] Depending on their location, tropical cyclones are referred to as hurricanes (Atlantic, Northeast Pacific), typhoons (Northwest Pacific), or cyclones (South Pacific and Indian Ocean).

Annex B

Steps of the recalibration process 2017/2018[25]

1) Determination of the list of material perils/regions

6.1. NCAs, respondents to a public consultation and national insurance associations provided input on the material inappropriateness of the previous calibration. This input was taken into account when determining the potential scenarios for recalibration. Relevant parameters for a scenario are: country, peril, country factor, zone relativity and aggregation matrix. In the recalibration only those perils/regions were considered where based on evidence received and an analysis performed by EIOPA a recalibration was needed.

6.2. The decision on which perils/regions to take into account for recalibration was based on considerations, such as:
- new model available;
- differences with trends from loss ratio obtained from collected historical losses and exposure and loss ratio used in the SF (requires collection of historical claims);
- changes in insurance system in a certain country (new national pool, new products);
- change in risk as a result of adaptation measures and exposure vulnerability.

2) Determination of the input to the recalibration: Models and industry exposure data

6.3. Two different types of information were needed for the recalibration: models and industry exposure data. The number of models significantly increased since the first calibration and models were available for most of the scenarios. In the case that industry exposure data was not available model owners had to use their own data.

3) Recalibration of the country factors

6.4. The recalibration started with the country factors because of their high impact on a (re)insurance undertaking's SCR for a given scenario. In order to identify a final proposal for a single country factor the following process was gone through ("mini Delphi method"): In a first step, models available for a given scenario were run and the values calculated were collected. In those cases were models were not available for a given scenario expert judgement was provided, using publicly available or sharable proprietary information. In a next step, the input values were anonymized and circulated to the experts. The experts then commented on the values and gave a vote either to increase or to decrease the value further (or keep it as it is). A comparison and subsequent consolidation of recommendations were carried out and comments to a "dominant set" of proposals were provided

[25] EIOPA's second set of Advice (EIOPA, 2018).

and re-circulated to the experts. The process was repeated until a single value was identified as the final proposal.

4) Decision on recalibration of more granular parameters

6.5. Based on the evidence provided by national stakeholders to EIOPA, it was assessed and decided if risk zone weights and/or aggregation matrices needed to be recalibrated.

5) Recalibration of risk zone weights and aggregation matrices

6.6. For the recalibration of risk zone weights and aggregation matrices relevant models were determined and industry exposure data was collected, the relevant model(s) were then run and generated a vector of raw risk zone weights and an aggregation matrix. In a next step an element-wise average for the vector and the matrix across the submitted sets of models used was formed. Experts commented on potential inconsistencies/peculiarities they discovered when assessing the appropriateness of each parameter (set). Finally, experts received the output of the previous step for final consistency checks.

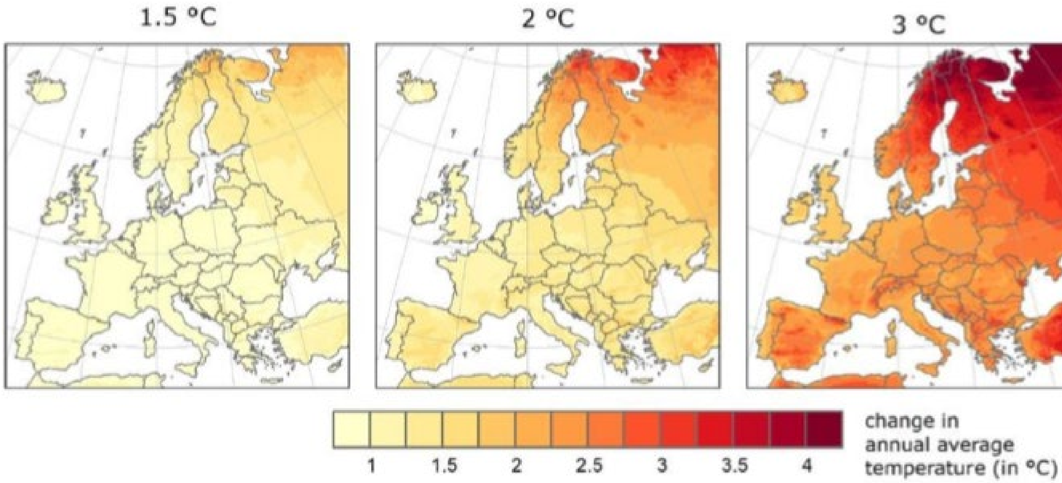
Annex C

Climate in Europe under global warming

7.1. The last five years (2015-2019) were the hottest years on record since 1850, when global average temperature started being tracked. Global average temperature is currently estimated to be 1.1°C above pre-industrial times (1850-1900) and 0.2°C warmer than 2011-2015 (WMO, 2019). PESETA IV uses the period 1981-2010 as a reference, when global average temperature was already 0.8°C higher on average compared to pre-industrial times (JRC, 2020).

7.2. Figure 10 shows the change in annual average temperature and precipitation across Europe between the reference period and the three warming scenarios of the project. Even when limiting global warming to 1.5°C (or 0.7°C in addition to the average warming over 1981-2010) a large fraction of Europe is projected to face an increase in temperature of 1°C or more relative to the reference period. Hence, the magnitude of warming is greater than the global average and not uniform over Europe. Under the 2°C and 3°C global warming scenarios, the spatial temperature differences become more apparent, with northern Europe and parts of southern Europe showing stronger warming.

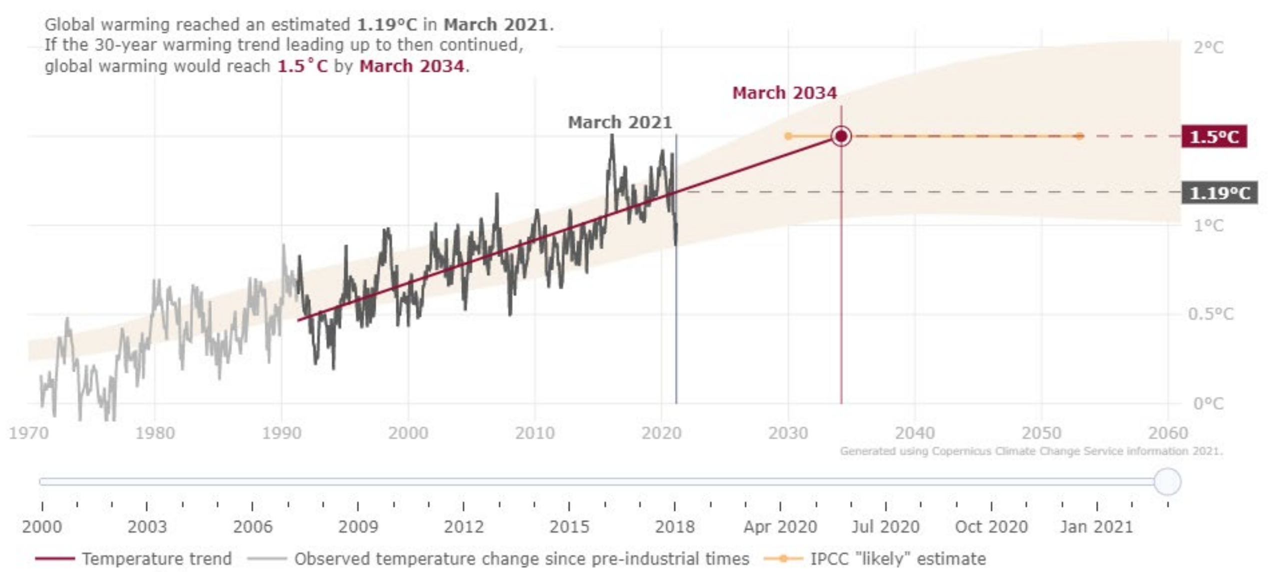
Figure 10. Changes from reference (1981-2010) in annual average temperature (top panels) for the three global warming scenarios used in PESETA IV (1.5°C, 2°C and 3°C warmer than pre-industrial times) (JRC, 2020).



7.3. In July 2020, climate data from the World Meteorological Organization (WMO) predicts that annual global temperature is likely to be at least 1°C warmer than preindustrial levels (defined as the 1850-1900 average) in each of the coming 5 years (2020-2024) and is very likely to be within the range 0.91 – 1.59°C and there is around 20 per cent chance that it will exceed 1.5°C in at least one year (WMO, 2020).

The Copernicus Climate Change Service (Copernicus, 2021) has developed an application – the 'Global temperature trend monitor' – to see the current rate of global warming and explore how soon we could reach the 1.5°C limit if warming continues at today's pace as presented in Figure 11. Updated on a monthly basis, the application provides a near real-time version of a graphic that originally appeared in the Intergovernmental Panel on Climate Change (IPCC) special report, 'Global Warming of 1.5°C'. The application shows that global warming reached an estimate of 1.19°C on March 2021 and shows that if the 30-year warning trend leading up to then continued, global warming would reach 1.5°C by 2034. It is interesting also to notice the estimated timing when global warming would reach 1.5°C is getting closer each year. In 2009, 1,5°C warming was estimated to be reached in 2050, in 2015, 1,5°C was estimated to be reached in 2045 and in 2020, 1,5°C warming is now estimated for to be reached in 2034.

Figure 11: A screenshot from the application 'Global temperature trend monitor'.



The yellow shaded area represents the uncertainty of the estimated 30-year average associated with past climate data and future climate projections and the orange line shows the likely estimate of when we will reach a warming of 1.5°C. Both are from the IPCC report, 'Global warming of 1.5°C'. Credit: Copernicus Climate Change Service, ECMWF.

Acute-climate-related hazards

7.4. Due to climate change, the frequency and severity of natural catastrophes is expected to increase. Improved climate projections provide evidence that future climate change will increase climate-related extremes (e.g. heat waves, heavy precipitation, droughts, top wind speeds and storm surges) in many European regions (EEA, 2017).

7.5. The following sections present the impact of climate change on a selection of natural catastrophe risk in Europe. The main sources for the description and analysis are the CLIM indicators published by the EEA[26] and the JRC PESETA IV project.

[26] CLIM indicators: https://www.eea.europa.eu/data-and-maps/indicators#c0=30&c12-operator=or&b_start=0&c10=CLIM.

7.6. EIOPA is using the final report of the EU Technical Expert Group on Sustainable Finance (TEG, 2020) as they created a classification specific for climate-related hazards and separate between chronic and acute climate-related hazards. The classification comprises four major hazard groups, with hazards related to water, temperature, wind, and mass-movements. All groups include acute (extreme) and chronic (slow-onset) hazards. EIOPA focuses on acute hazards, this below section will therefore only consider acute hazards. Avalanche or landslide are not treated here as they are less material for the insurance sector.

Table 6: Classification of climate-related hazards.

	Temperature-related	**Wind-related**	**Water-related**	**Solid mass-related**
Chronic	Changing temperature (air, freshwater, marine water)	Changing wind patterns	Changing precipitation patterns (rain, hail, snow/ice)	Coastal erosion
	Heat stress		Precipitation and/or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	Soil erosion
	Permafrost thawing		Saline intrusion	Solifluction
			Sea level rise	
			Water stress	
Acute	Heat Wave	Tropical cyclone	Drought	Avalanche
	Cold wave/frost	Windstorm (including blizzards, dust and sandstorms)	Heavy precipitation (rain, hail, snow/ice)	Landslide
	Wildfire	Tornado	Flood (coastal, fluvial, pluvial, ground water)	Subsidence
			Glacial lake outburst	

Temperature-related

Wildfire

7.7. Fires play an essential role in the dynamics of many ecosystems. They are an essential element of forest renewal, they help control insect and disease damage, and they reduce the build-up of fuel and thus the intensity of future fires. On the other hand, forest fires are a significant disturbance agent in many forested landscapes. Frequent and large-scale fires have negative impacts on air and water quality, threaten biodiversity, increase the risks of soil erosion and spoil the aesthetics of a landscape. Forest fires also represent a threat to climate change mitigation, as they release large amounts of greenhouse gases while removing natural carbon sinks. Furthermore, forest fires can cause large economic damages and losses of human lives if they affect populated areas.

7.8. Fire risk depends on many factors such as climatic conditions (e.g. humidity, temperature and wind), vegetation (e.g. fuel load and condition), topography, forest management practices and the socio-economic context. The large majority of wildfires in Europe are ignited by humans, either accidently or intentionally. However, climatic factors and the availability of fuel determine the conditions under which fires occur and spread, once ignition has occurred. The extreme fire episodes and devastating fire seasons of recent years in Europe were, in most cases, driven by severe fire weather conditions. Thus, climate change is expected to have a strong impact on forest fire regimes in Europe.

Current Impact of Climate Change

7.9. The EEA analysis (EEA, 2017) shows that the burnt area in the Mediterranean region has shown a slightly decreasing trend since 1980, but with high interannual variability; the meteorological fire hazard has increased over the same period as a result of global climate change. These opposite trends suggest that efforts to improve fire management have generally been successful.

7.10. Large forest fires in recent years have affected various regions in northern and Western Europe in which fires were not prevalent in the past. More European countries suffered from large forest fires in 2018 than ever before, and Sweden experienced the worst fire season in reporting history. The unprecedented forest fires in several European countries in 2017 and 2018 coincided with record droughts and heatwaves in these years.

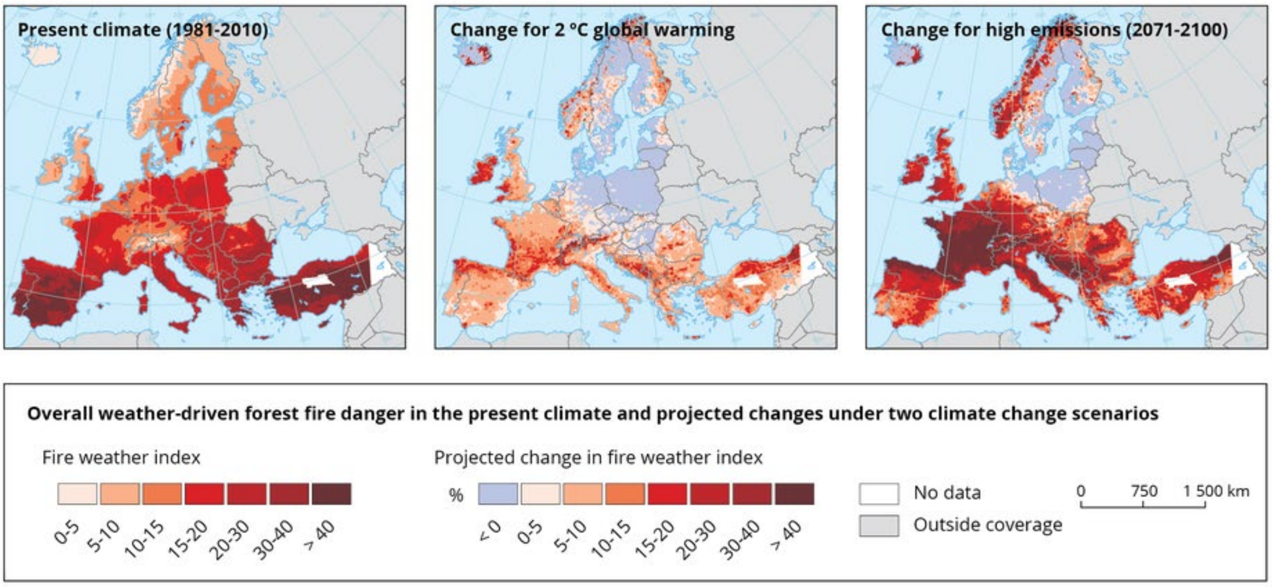
Short and long-term Impact of Climate Change

7.11. Drier weather and, as a consequence, substantial expansion of the fire-prone area and longer fire seasons are projected in most regions of Europe, in particular for high emissions scenarios. The increase in fire danger is projected to be particularly large in western-central Europe, but the absolute fire danger remains highest in southern Europe. Adaptation measures, such as improved fire prevention and suppression, can substantially reduce fire risks.

7.12. Climate change projections suggest substantial warming and increases in the number of heat waves, droughts and dry spells across most of the Mediterranean area and more generally in southern Europe, which would increase the length and severity of the fire season, the area at risk and the probability of large fires, possibly enhancing desertification.

7.13. Figure 12 shows weather-driven fire danger for the present climate and for projected climate conditions under two emissions scenarios, as calculated in the JRC PESETA III project (JRC, 2018). These projections show marked increases in fire danger in most European regions, with the exception of parts of north-eastern and northern Europe. These changes are more pronounced for higher than for lower emission scenarios. The increase in fire danger would be particularly strong in western central Europe, leading to a northward expansion of the zones at moderate fire danger. However, the countries with the highest absolute danger remain Portugal, Spain and Turkey. The projected increase in fire risk in southern Europe are robust across different modelling approaches whereas the projections for northern Europe are more uncertain.

Figure 12: Forest fire danger in the present climate and projected changes under two climate change scenarios (JRC, 2018).



Wind-related

Windstorm

7.14. Windstorms are amongst the most damaging natural hazards in Europe, with approximately 5 €billion of estimated annual losses in the EU. The number of reported windstorms has increased significantly over the last decades, yet there is no consensus about a climate-induced trend in windstorms over Europe.

Current Impact of climate change

7.15. As presented in the JRC PESETA IV project (JRC, 2020), during the last few decades, Europe was hit by a number of highly damaging windstorms that caused a considerable human and economic impact, ranging from human fatalities and injuries to damage to roads, power plants, the agriculture sector, forests, infrastructure, and private properties. Estimated average annual losses for EU and UK amount to 5 €billion/year (in 2015 values), or approximately 0.04% of total GDP (of 2015). Absolute losses are highest in Germany (850 €million/year), France (680 €million/year), Italy (540 €million/year) and the UK (530 €million/year), while impacts relative to the size of the economy are double the EU average in Bulgaria and Estonia (0.08% of GDP), and 0.07% of GDP in Latvia, Lithuania and Slovenia. While in tropical regions an increase in the frequency and intensity of tropical cyclones has been observed in the last decades, in particular from the 1990's, in Europe there is no robust trend in windstorms.

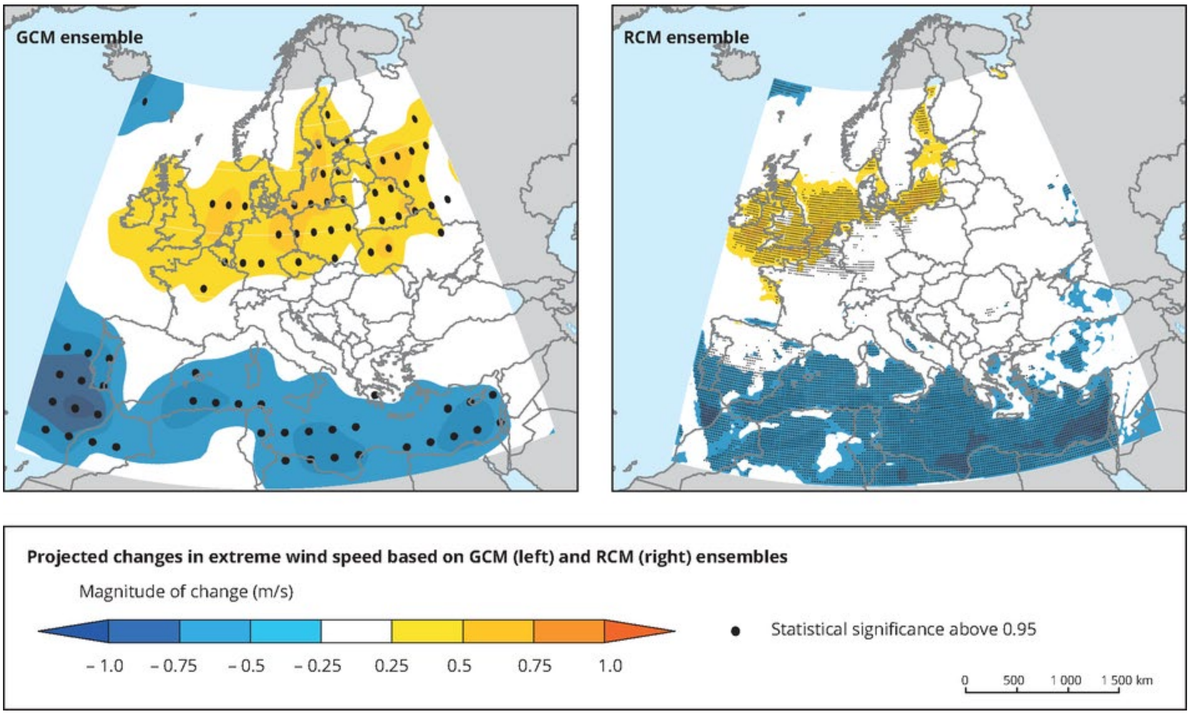
Short and long-term Impact of Climate Change

7.16. Climate model projections of extreme winds suggest that windstorms will not become more intense or happen more frequently with global warming over most of the European land. As a consequence, it is expected that risk from windstorms in the EU will not rise due to climate change.

7.17. EEA analysis (EEA, 2020) also concludes that storm location, frequency and intensity have shown considerable decadal variability across Europe over the past century, such that no significant long-term trends are apparent. Recent studies on changes in winter storm tracks generally project an extension eastward of the North Atlantic storm track towards central Europe and the British Isles.

7.18. Climate change simulations show diverging projections on changes in the number of winter storms across Europe. However, in the recent past most studies agreed that the risk of severe winter storms, and possibly of severe autumn storms, will increase for the North Atlantic and northern, north-western and central Europe towards the end of the 21st century, as shown on Figure 13.

Figure 13: Projected changes in extreme wind speed



Note: Changes in extreme wind speed (defined as the 98th percentile of daily maximum wind speed) for A1B (2071–2100) relative to 1961–2000. Left: based on 9 general circulation models (GCMs). Right: based on 11 regional climate models (RCMs). Coloured areas indicate the magnitude of change (unit: m/s), statistical significance above 0.95 is shown by black dots.

7.19. However, recent studies hinted at still substantial uncertainties about the future windstorm outlook. A novel approach in climate modelling, including a module which for the first time implemented an interactive stratospheric ozone chemistry module, demonstrated that the retreat of Arctic sea ice could result in more episodes in mid- to late winter and spring when the polar vortex is weakening, leading to cold air outbreaks (Romanwosky et al., 2019) and conditions not supportive to increased windstorm activity in the North Atlantic - European sector. As a consequence, it is also possible that the winter windstorm activity in the future will either stay constant or even decrease in some regions (Zappa and Shepherd, 2017).

7.20. For wind gusts from thunderstorms in the summer half year, recent studies adopting a new approach to infer thunderstorm hazard activity from thunderstorm-prone environmental fields of moisture, wind shear and instability, report the following findings: Increases in the frequency of wind gust events greater than 25 m/s over the period 1979-2016 were found in particular for regions of the alpine and Balkan countries. For the future, an increase in the frequency of such wind gust events for large parts of Europe is projected (Rädler et al., 2018; Rädler et al., 2019).

Water-related

Heavy precipitation

7.21. Changes in the frequency and magnitude of heavy precipitation events can have considerable impacts on society, including on agriculture, industry and ecosystem services. An assessment of past trends and future projections of heavy precipitation is therefore essential for advising policy decisions on mitigation and adaptation to climate change.

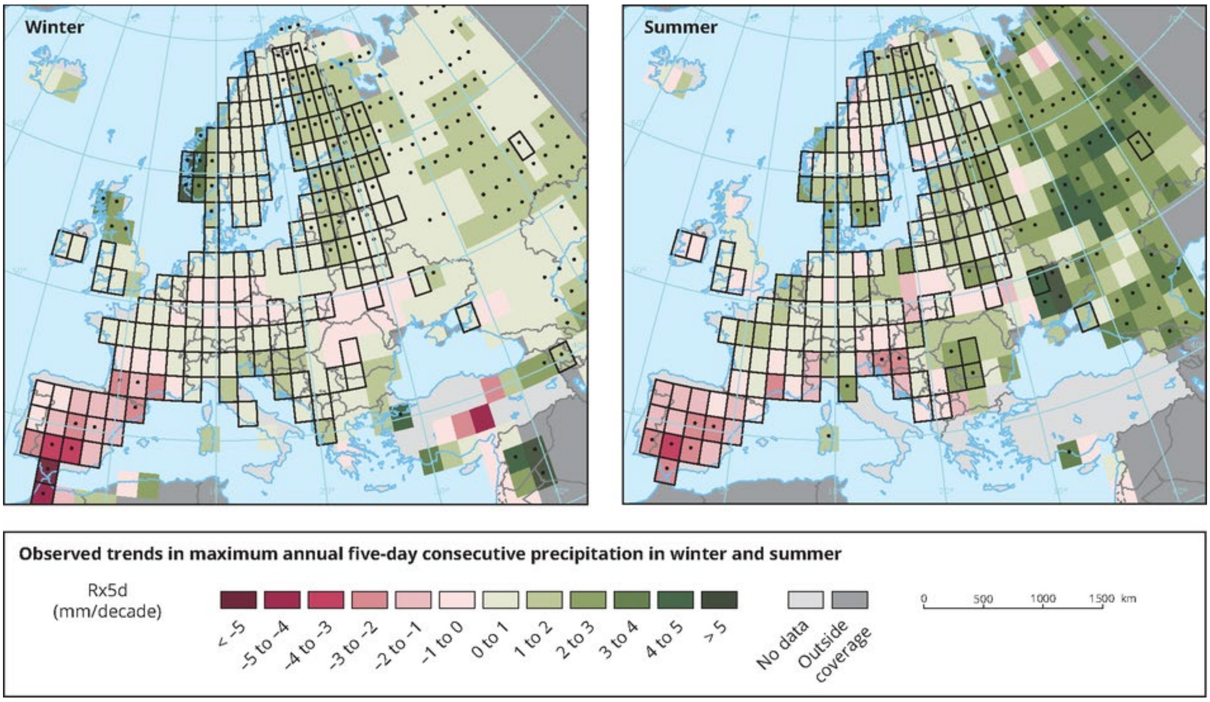
7.22. Flooding events including pluvial floods and flash floods are directly linked to heavy precipitation hazards. The risks posed by heavy precipitation hazards are also influenced by non-climatic factors, such as population density, floodplain development, defences and land-use changes. Hence, estimates of future changes in such risks need to consider changes in both climatic and non-climatic factors.

Current Impact of Climate Change

7.23. The EEA analysis (EEA, 2020) shows that the intensity of heavy precipitation events in summer and winter have increased in northern and north-eastern Europe since the 1960s. Different indices show diverging trends for south-western and southern Europe.

7.24. Figure 14 shows the observed trend in maximum annual five-day precipitation over Europe between 1960 and 2018 for winter (December-January-February) and summer (June-July-August). The change is expressed in mm/decade. Grid boxes outlined in solid black contain at least three stations and so are likely to be more representative of the grid box. Significant (at the 5% level) long-term trend is shown by a black dot.

Figure 14: Observed trends in maximum annual five-day consecutive precipitation in winter and summer

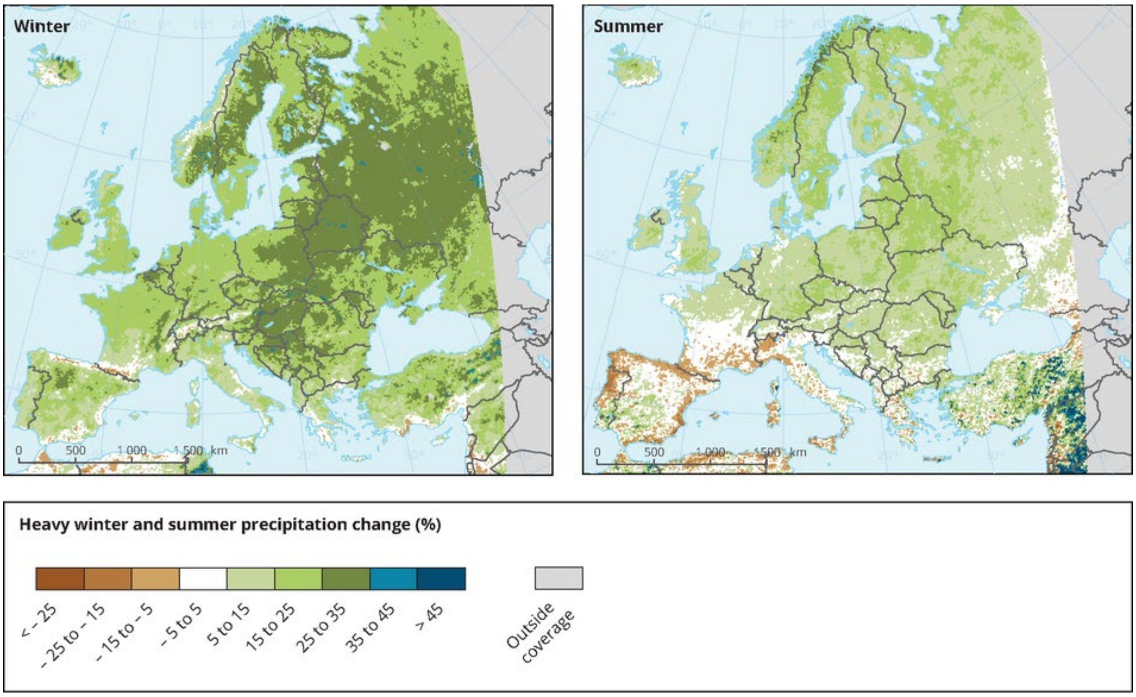


<u>Short and long-term Impact of Climate Change</u>

7.25. Heavy precipitation events are likely to become more frequent in most parts of Europe. The projected changes are strongest in Scandinavia and northern Europe in winter.

7.26. Figure 15 presents the projected changes in heavy precipitation (in %) in winter and summer from 1971-2000 to 2071–2100 for the RCP8.5 scenario based on the ensemble mean of different regional climate models (RCMs) nested in different general circulation models (GCMs).

<u>Figure 15: Projected changes in heavy precipitation in winter and summer</u>



River floods

7.27. River flooding is one of the costliest natural disasters in Europe. Global warming and continued development in flood prone areas will progressively increase river flood risk. Adequate adaptation strategies can substantially reduce future flood impacts.

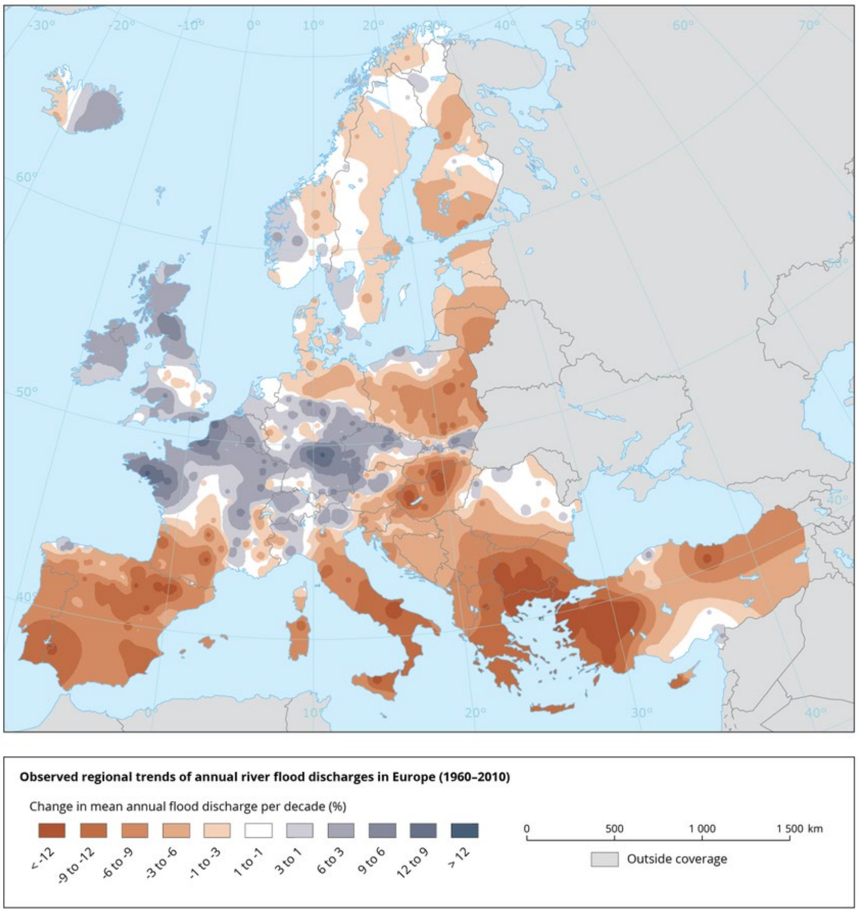
Current Impact of Climate Change

7.28. PESETA IV estimates that at present river flooding causes damage of 7.8 €billion/year in the EU and UK, which is equivalent to around 0.06% of current GDP. Moreover, more than 170,000 people every year are exposed to river flooding.

7.29. Studies from the EEA reveals that annual river discharges increased in north-western and parts of central Europe but decreased in southern and north-eastern Europe over the period 1960-2010 because of climate change.

7.30. The map on Figure 16 based on the European flood database and analysis from Hall et al. (2015) shows the linear trend in the annual maximum of daily river discharge over the period 1960-2010. Blue indicates increasing flood discharges and red denotes decreasing flood discharges (in per cent change of the mean annual flood discharge per decade).

Figure 16: Observed regional trends in annual maximum daily river discharges in Europe (1960–2010)

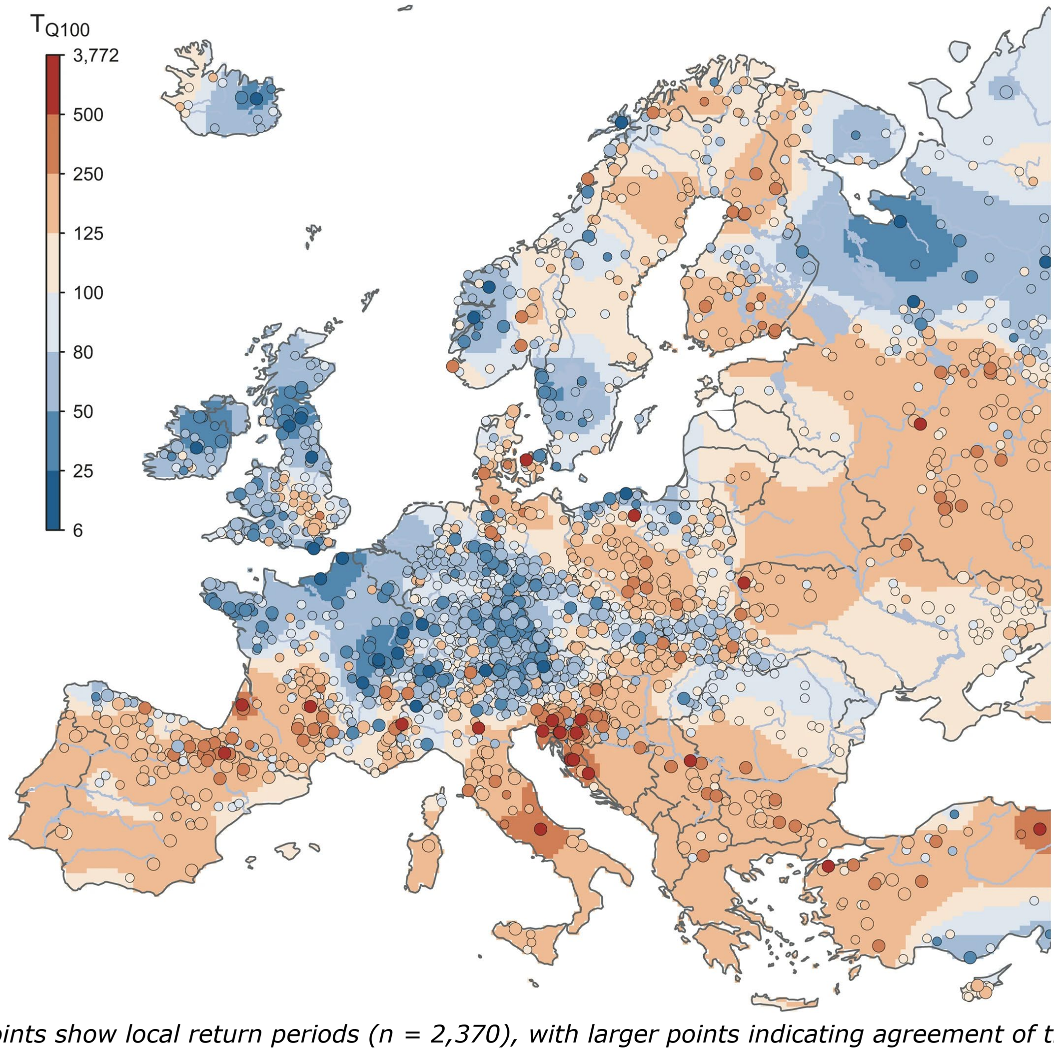


7.31. Note that Figure 16 covers mostly floods in medium and large catchments, which are caused by long-duration synoptic storms. In contrast, floods in small basins are typically caused by local convective storms, which are increasing in a warmer climate. This means that in the Mediterranean, small floods may have increased even though medium and large floods have decreased (Blöschl et al., 2019)

7.32. Whereas Figure 16 shows changes in annual maximal daily flood levels, the largest damages are caused by more extreme flood events. A study from Bertola et al. (2019) based on the European Flood Database found that trends in the once-in-a-century flood in Europe show a similar geographical pattern as trends in mean floods over the period 1960–2010, with some variations depending on the region and the size of the catchment area. Therefore, the trends shown in Figure 17 are a reasonable proxy for trends in more extreme floods.

7.33. Figure 17 from Blöschl et al. (2019), shows that for some regional areas of Central Europe and Western Europe peak discharges that were a 100-year event in 1960 have become a 50-year event in 2010, for larger parts this has become a 80-year to 50-year event.

Figure 17: Estimated return period in the year 2010 for the peak flood discharge per year which was a 100-year event in 1960.



Points show local return periods (n = 2,370), with larger points indicating agreement of the 5th and the 95th percentiles of the uncertainty distribution in the sign of change. The background *pattern represents regional return periods. Blue indicates lower return periods, representing increasing flood discharges, and red indicates higher return periods, representing decreasing flood discharges. This figure provides a continental overview and does not replace national-scale and local studies, for which more detailed information may be available*

Short and long-term Impact of Climate Change

7.34. Global warming will progressively increase flood frequency and severity in most of Europe. At the same time, the projected social and economic growth will further increase exposure to flood events. PESETA IV estimates that if no mitigation and adaptation measures are taken, economic losses will grow to nearly 50 €billion/year with 3°C global warming by the end of this century, or more than 6 times compared to present, while nearly 3 times as many people would be exposed to flooding. Limiting global warming to 1.5°C would halve the economic losses and population exposure to river flooding relative to unmitigated climate (Figure 18).

Figure 18. Annual flood damage and population exposed to river flooding for EU and UK in the present and by 2100 for different levels of global warming, with and without adaptation respectively (JRC, 2020).

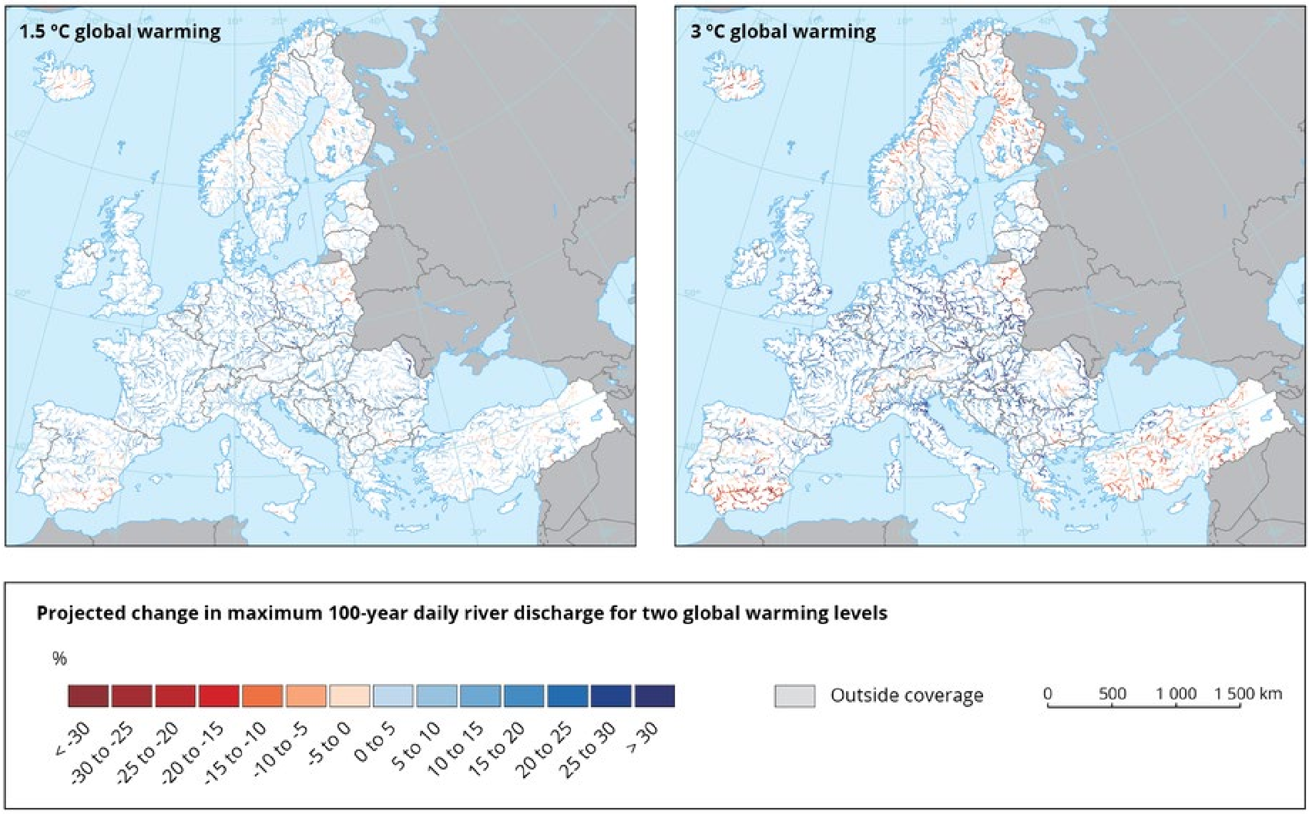
	Today	2100 - no adaptation			2100 - adaptation		
		1.5˚C	2˚C	3˚C	1.5˚C	2˚C	3˚C
Damage (€ billion/year)	7.8	24	33	48	8.6	9.6	8.6
People exposed (1000/year)	172	252	338	482	92	100	90

7.35. The "no adaptation" scenario refers to present-day flood protection measures. The "adaptation" scenario is based on the implementation of retention areas to store excess flood water to a level of protection that maximises their economic benefit.

7.36. Future climate change is projected to increase the occurrence and frequency of once-in-a-century river floods in most regions of Europe, with the exception of parts of northern Europe, southern Spain and Turkey. Pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe.

Figure 19: Projected change in maximum 100-year daily river discharge for two global warming levels[27]

[27] To access figure with better resolution: https://www.eea.europa.eu/data-and-maps/figures/projected-change-in-maximum-100.



Hail

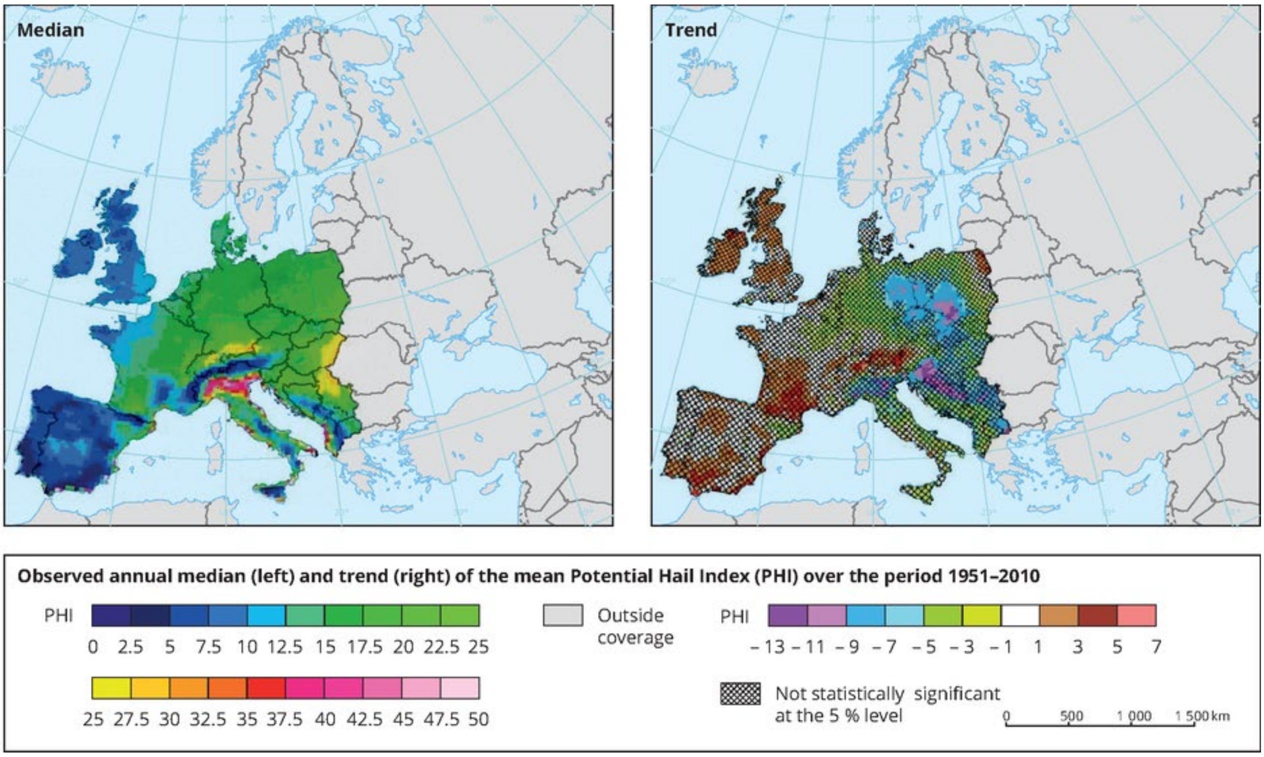
7.37. Hail events are among the costliest weather-related extreme events in several European regions, causing substantial damage to crop, vehicles, buildings and other infrastructure.

<u>*Current Impact of Climate Change*</u>

7.38. The number of hail events is highest in mountainous areas and pre-Alpine regions. Since 1951, increasing hail trends have been noted in southern France and Austria, and decreasing (but not statistically significant) trends have been noted in parts of Eastern Europe.

7.39. Recently, European hail climatology for the period 1951–2010 was analysed using a combination of various meteorological parameters relevant for thunderstorms and hail. This has been expressed as the potential hail index (PHI), which quantifies the atmospheric potential for hailstorms. The climatology shows the highest values of the mean PHI for the areas north and south of the Alps, the eastern Adriatic coast and parts of Eastern Europe (Figure 20 left). Increasing hail trends (with a PHI over 3 in the period 1951–2010) are found in southern France and Spain and decreasing trends (with a PHI lower than −5 in the period 1951–2010) in Eastern Europe (Figure 20 right). However, trends are not significant (at the 5 % significance level) in most grid boxes.

<u>Figure 20: Observed annual median and trend of the Mean Potential Hail Index (PHI) over the period 1951-2010.</u>



7.40. An alternative meteorological analysis approach using thunderstorm-prone environmental fields of moisture, instability, and vertical wind shear, which can be diagnosed from both reanalysis and climate model data, found increases in hail events with hailstone diameters exceeding 2 cm over a period 1979-2016 particularly in regions of alpine countries including northern Italy and Balkan countries (Rädler et al., 2018).

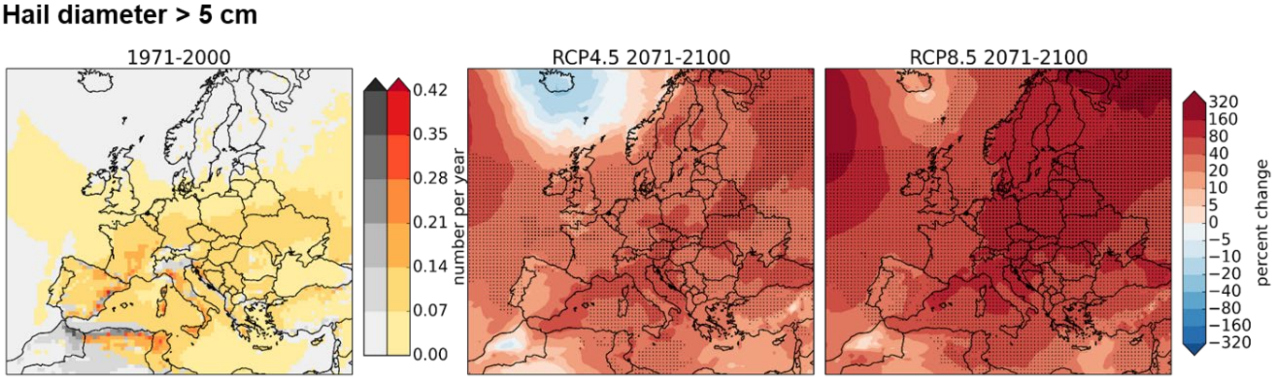
Short and long-term Impact of Climate Change

7.41. Future projections of hail events are subject to large uncertainties, because small-scale hail events cannot be directly represented in global and regional climate models. However, model-based studies for central Europe show some agreement that hailstorm frequency will increase in this region. A novel climate modelling approach (Rädler et al., 2019, see also above) that does not rely on spatially resolving convective cells in climate models but instead inferring hail probabilities from hailstorm-prone environmental parameter fields, is projecting clear increases of storms with hail stone diameters greater than 2 cm and greater than 5 cm all over Europe. For hail diameters exceeding 5 cm, the change in event frequency by the end of the 21st century relative to 1971-2000 is shown for two future scenarios (RCP4.5[28] and RCP8.5[29]) in Figure 21.

[28] RCP 4.5 is one intermediate pathway and refers to the concentration of carbon that delivers global warming at an average of 4.5 watts per square meter across the planet. The RCP 8.5 pathway delivers a temperature increase of about 1.7 to 3.2°C by 2100, relative to pre-industrial temperatures.

[29] RCP 8.5 is one high pathway and refers to the concentration of carbon that delivers global warming at an average of 8.5 watts per square meter across the planet. The RCP 8.5 pathway delivers a temperature increase of about 3.2 to 5.4°C by 2100, relative to pre-industrial temperatures.

Figure 21: Projected percent changes in the frequency of hail events with hailstone diameters greater than 5 cm in 2071-2100 relative to 1971-2000 for RCP4.5 and RCP8.5 (Rädler et al., 2019).



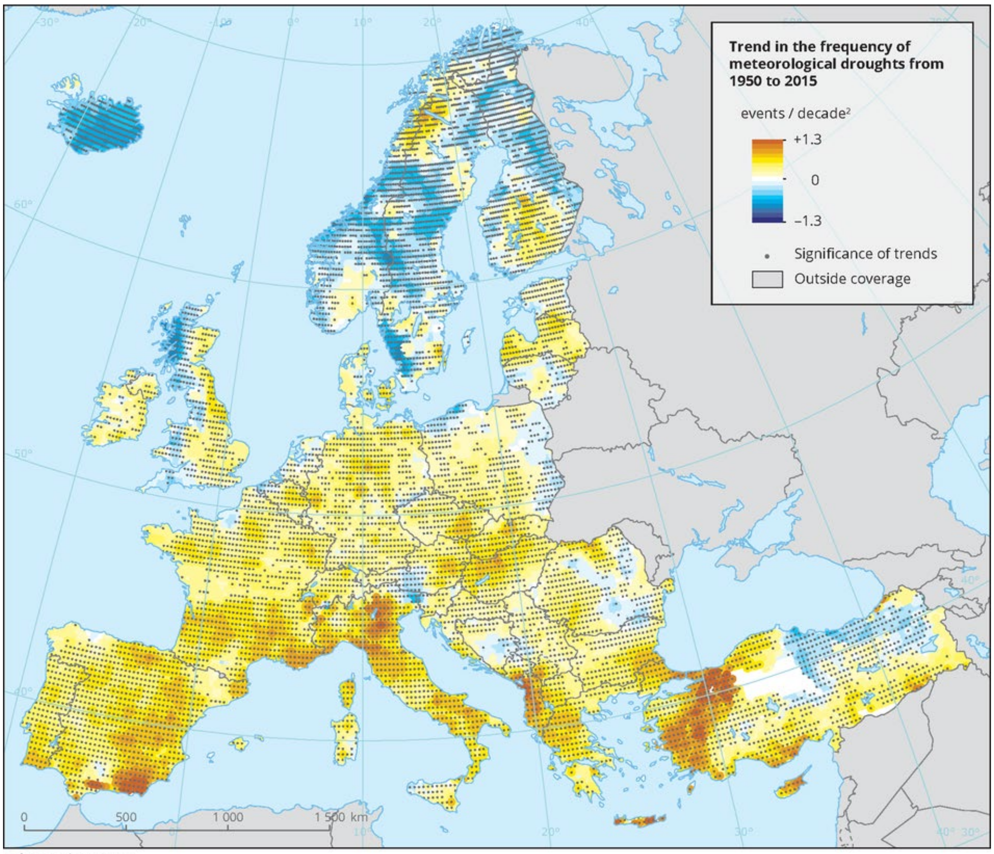
Drought

7.42. Drought is a recurrent feature of the European climate that affects considerable fractions of the European population each year.

Current Impact of Climate Change

7.43. The frequency and severity of meteorological (i.e. precipitation deficit) and hydrological (i.e. low runoff or river flow deficit) droughts have increased in most parts of Europe. Different drought indices agree that the increase is greatest in southern Europe.

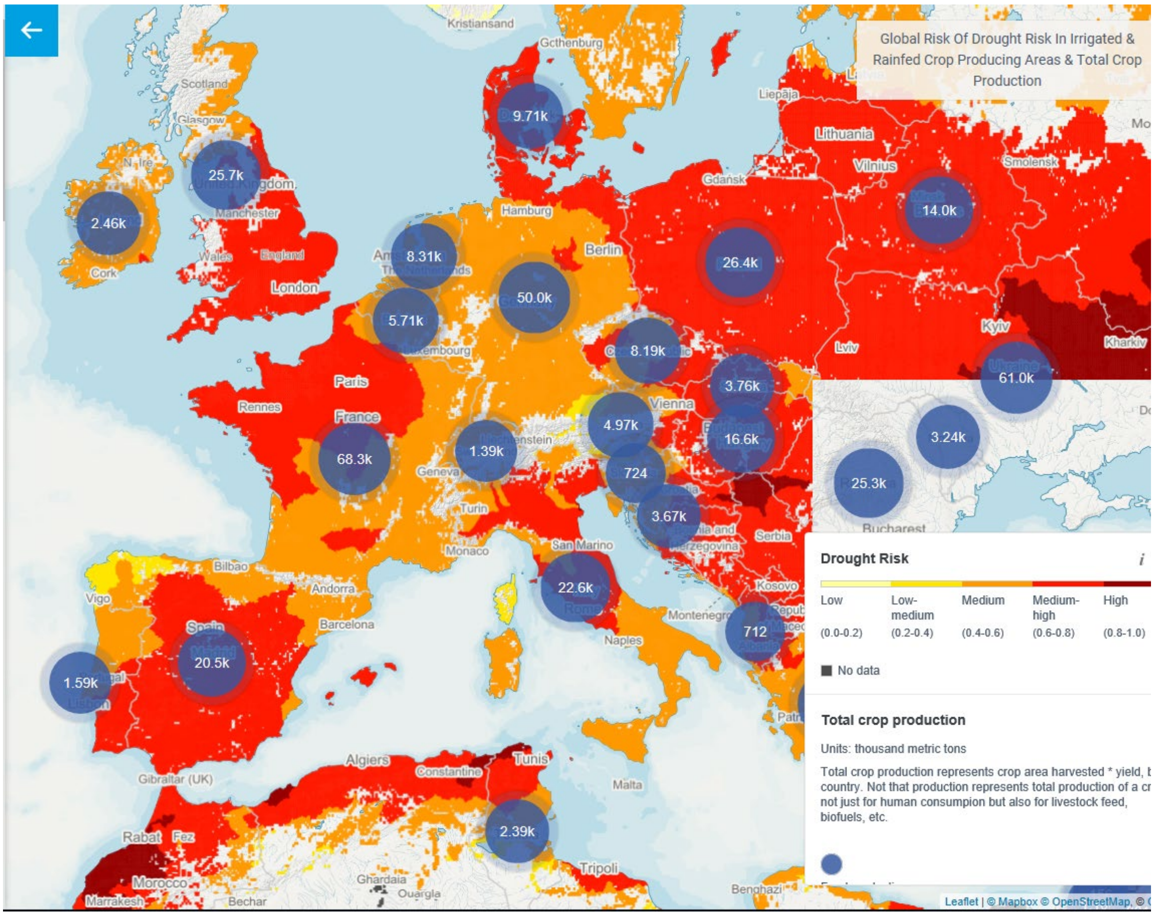
Figure 22: Trend in the frequency of meteorological droughts in Europe (1950-2015)



Reference data: ©ESRI

7.44. Drought risk is especially impacting crop production as shown in Figure 23.

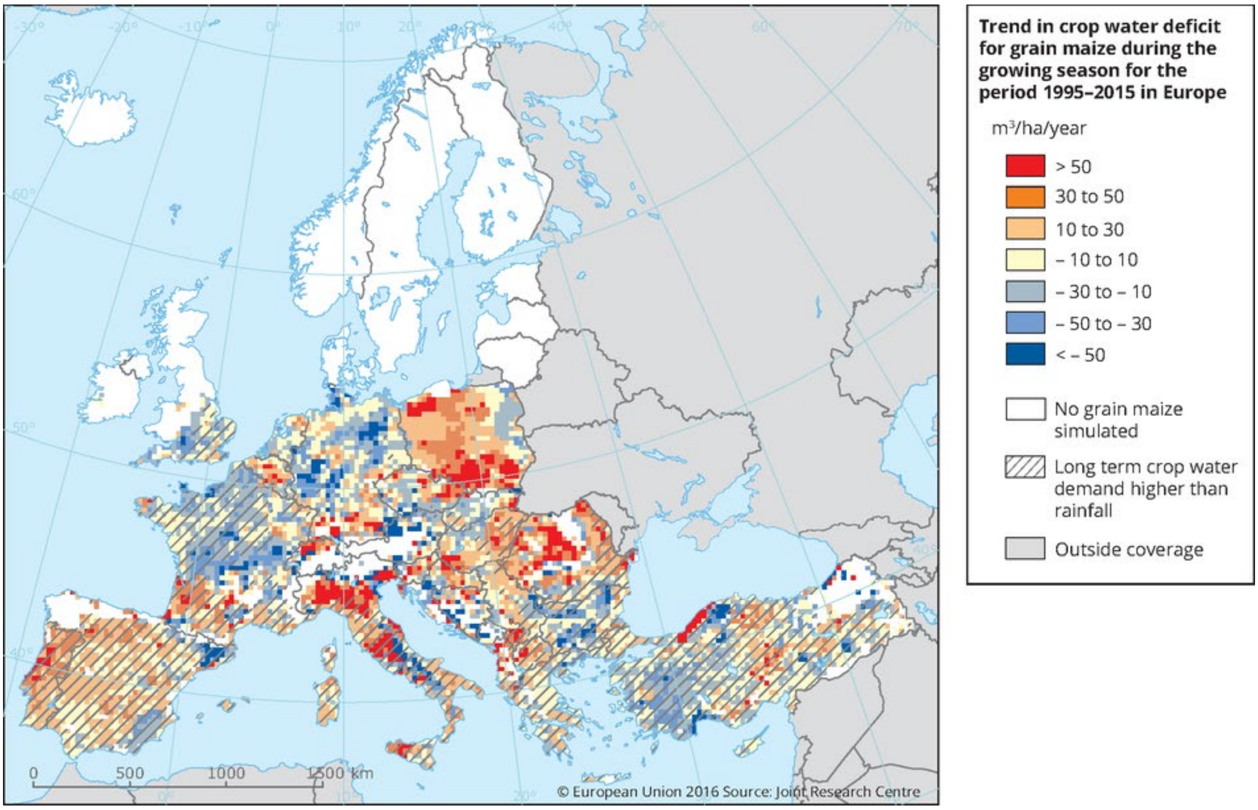
Figure 23: Drought risk on crop production (source: Aqueduct[30])



7.45. Climate change led to an increase in the crop water demand and thus the crop water deficit from 1995 to 2015 in large parts of southern and eastern Europe; a decrease has been estimated for parts of north-western Europe. The projected increases in temperature will lead to increased evapotranspiration rates, thereby increasing crop water demand across Europe.

Figure 24: Trend in crop water deficit of grain maize during the growing season

[30] https://www.wri.org/aqueduct



Annual rate of change of the crop water deficit of grain maize during the growing season for the period 1985-2014 in Europe. The crop water deficit is the difference between the crop-specific water requirement (in this case grain maize) and available water through precipitation. The simulation is based on the JRC-MARS gridded meteorological data at 25 km resolution. Red colours show an increase of the gap between crop water requirement and the available water, blue colours indicate a reduction of the deficit. Areas where the seasonal crop water requirement exceeds regularly (i.e. in more than 90 % of the years) the available water (through precipitation) have been marked by hatches. Areas without hatches experience both deficit and surplus or only a surplus of water in their crop water balance. In this case, red colours refer to a reduced surplus, while blue colours indicate an increasing surplus of available water.

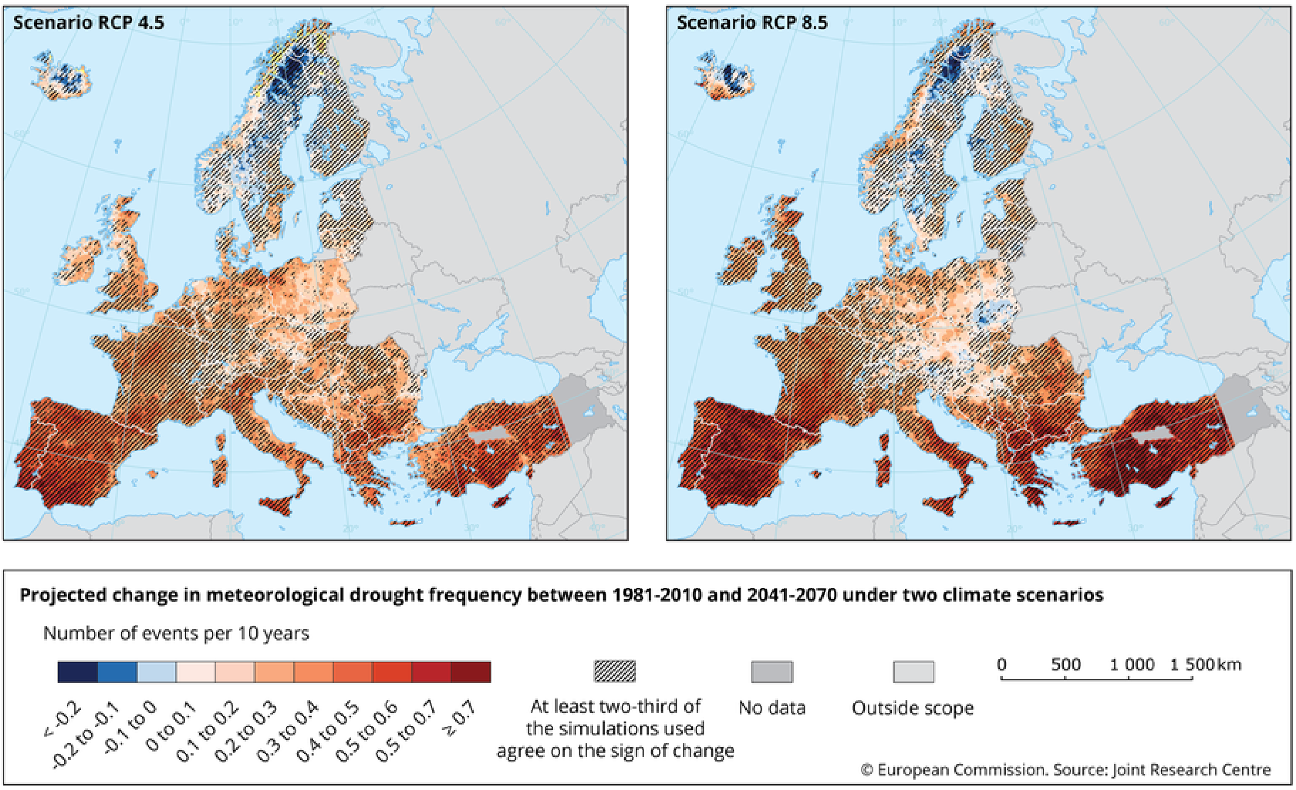
Short and long-term Impact of Climate Change

7.46. Available studies project further increases in the frequency, duration and severity of meteorological and hydrological droughts for most of Europe during the 21st century, except for parts of central-eastern and north-eastern Europe. The greatest increase in drought conditions is projected for southern Europe where it will increase competition between different water users, such as agriculture, industry, tourism and households.

7.47. Figure 25 shows projected changes in the frequency of meteorological droughts (SPI-3, see above) by the mid-21st century (2041-2070 compared with 1981-2010) for two emissions scenarios: RCP4.5 (left) and RCP8.5 (right). These projections show increases in meteorological droughts across most of Europe, in particular southern Europe, whereas decreases in droughts are only projected for limited parts of northern Europe. The changes are most pronounced for the high emissions scenario (RCP8.5) and slightly lower for the moderate scenario (RCP4.5).

7.48. Projections using drought indices that also consider potential evapotranspiration (e.g. based on the SPEI, the Standardized Runoff Index (SRI) or the Supply–Demand Drought Index (SDDI)) show substantially greater increases in the areas affected by drought than those based on the precipitation-based SPI alone, because increasing temperatures lead to increasing evapotranspiration

Figure 25: Projected change in meteorological drought frequency between the present (1981-2010) and the mid-century 21st century (2041-2070) in Europe, under two emissions scenarios



Solid mass-related

Subsidence

7.49. Subsidence is defined as a clay-related geo-hazard capable of causing harm to build environment and life as consequence, which is a result of soils shrinking and swelling according to wetting and drying conditions. Indeed, high temperatures are drying up the air and thus enhancing evapotranspiration. Depending on the soil type, the shrinking of soil volume with evapotranspiration can be substantial, in particular for clay soils.

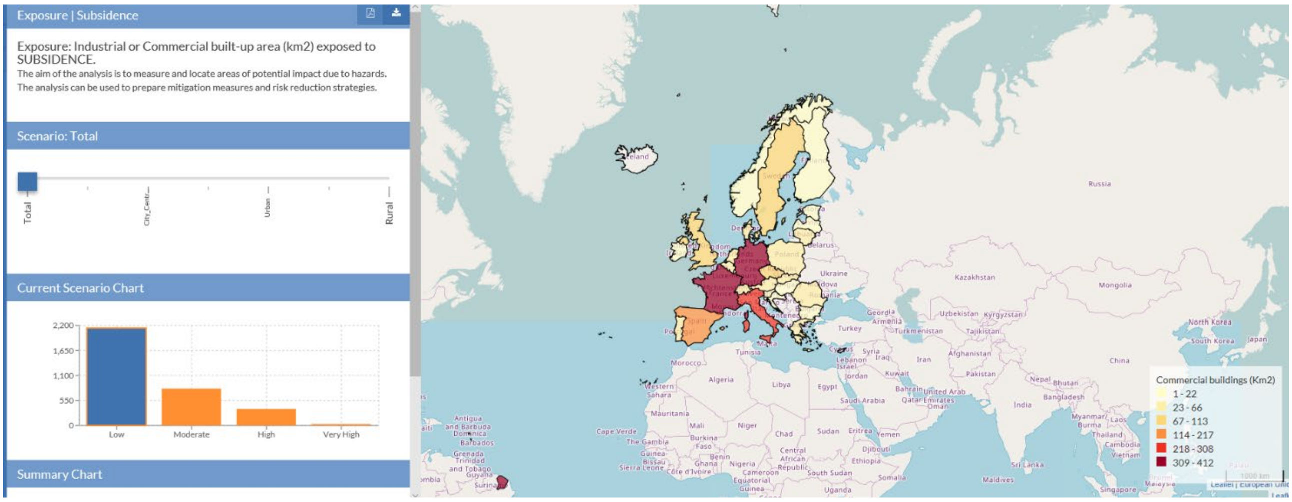
7.50. As presented by Swiss Re (2011), a long and intense dry spell can lower the ground so much that it creates fissures in the earth and tears apart the foundations of houses, bridges, industrial sites and other structures. In the worst case, shifting soil can cause whole buildings to collapse. Climate change will magnify the risks.

Current, short and long-term Impact of Climate Change Impact of Climate Change

7.51. As presented earlier in this chapter, the frequency and severity of droughts have increased in most parts of Europe as a consequence of climate change. This drier weather trend has already altered soil moisture conditions across Europe in recent years. As the trend continues, occurrences of drought and soil subsidence will become even more frequent and more severe in the coming years.

7.52. Figure 26 indicates the potential for clay-related subsidence to be present, with regard to the amount of clay content of the soils on which the high activity and plasticity index of the soils is based on. The subsidence susceptibility is given by the clay (<0.002mm) proportions of the soils texture.

Figure 26: Potential for clay-related subsidence to be present[31].



[31] https://drmkc.jrc.ec.europa.eu/risk-data-hub/#/./#/

Annex D

8.1. This annex includes the options which were mentioned in the discussion paper under public consultation from Dec. 2020 to Feb 2021 but which will not be considered further.

Assess the need to include other insurance activities

8.2. This approach suggested that in light of climate change additional insurance activities should be added to the ones currently covered by the SF.

8.3. How could it be implemented?: Currently, the LoBs fire and other damage, marine aviation transport and motor are considered in the Nat Cat SCR SF module (see Table 7). In addition to these LoBs, one could consider if crop insurance could be added in light of the impact of climate change in perils such as droughts which could significantly affect agricultural insurance.

Table 7: Current and potential future insurance activities considered in the SF for Nat Cat per peril.

	Earthquake	Flood	Windstorm	Hail	Subsidence	Drought
Fire and other damage	x	x	x	x	x	
Marine Aviation Transport	x	x	x	x		
Motor property damage		x		x		
Crop damage		?		?		**?**

8.4. The agricultural insurance landscape in the European Union (EU) is diverse. Member states are facing different types of risks, and also the cultural and political environment varies between member states. In addition, the so-called risk management toolbox of the common agricultural policy (CAP) authorises public support for different tools including insurance, mutual funds and income stabilisation tools[32] .

8.5. Regarding crop insurance covering climatic risks, the largest multiple peril crop insurance (MPCI) programs are in France, Spain and Italy (Bardaji et al., 2016; Santeramo et al., 2018), while Germany has a mature single-peril hail insurance market for crops (Reyes et al.,2017). In Hungary and Poland, crop insurance is partly obligatory (Wąs and Kobus, 2018). In the Netherlands, commercial hail insurance is marketed next to supported MPCI (Van Asseldonk et al., 2018), whereby MPCI schemes are offered mostly through mutual funds.

[32] http://ec.europa.eu/agriculture/cap-post-2013/legislation/index_en.htm.

8.6. From a model vendors' perspective, commercial model vendors currently offer multiple peril crop insurance (MPCI) models for China, India and the USA. The models assess the impact of weather on crop yields using a probabilistic approach to quantifying multiple peril crop risk provides a comprehensive view of realistic loss scenarios, given current crop genetics, exposure, weather data, management practices, and policy conditions. No commercial models are offered yet by the typical model vendors for modelling crop insurance in Europe. In Spain for example, the agricultural insurance works with universities and research institutions in order to have a prospective analysis of the risks covered.

8.7. Another LoB, which could be considered, is Non-Damage Business Interruption (NDBI). Indeed, some businesses, such as aviation companies for example might not be able to continue operating after a catastrophic event, even if they were not physically impacted. Standard basic BI insurance policies will usually cover an insured for losses arising from interruption to his business as a result of damage to insured property. NDBI is therefore only covered in a limited number of insurance contracts. In light of climate change, NDBI losses might also increase when businesses cannot operate further due to low water level of rivers for example (C&EN, 2018). It would therefore be necessary to monitor how this type of insurance coverage is evolving with time.

8.8. EIOPA would also need to get access to loss data in order to monitor changes over time. EIOPA decided to not consider this option as a separate point for future calibration to include climate change in the nat cat SF as the estimated materiality of additional LoBs to the insurance sector is expected to be low. EIOPA will however monitor additional risks such as crop insurance in the context of increase drought risks.

Add a loading factor for specific perils/regions

8.9. This approach suggested to add a loading factor to account for additional climate change risk.

8.10. The rationale behind this approach is that it might be easier to add a loading factor on top than to perform a complete recalibration of the parameters. However, it is extremely difficult to estimate such a loading factor for different perils/countries because it would require to dissociate the issue of climate change which cannot be disentangled (attribution issue is very difficult). This would add a lot of complexity and no certainty that climate change has been properly captured. In addition, one might also have recent historical data used for the recalibration, which already includes climate change so that this approach could lead to a "double inclusion".

8.11. Such an approach could have been implemented by adding a loading factor in the Delphi process when the final parameter is chosen (to add a loading factor on the final parameters to reflect the fact that additional uncertainty might come from climate change or go for a more conservative (prudential) choice of the parameter).

Capture climate change in the spatial and peril correlation

8.12. This approach was aimed at looking at the correlation matrices and ensure that they properly reflect climate change effects.

8.13. Spatial and peril correlation is an aspect of the recalibration that could contribute significantly both to the effort required to recalibrate as well as the impact to firm’s capital requirement. For instance, the correlation across perils could materially change the overall loading more than the individual peril re-calibration exercise.

8.14. Climate change has the potential to alter the current spatial and peril dependencies, especially in the tail of the distribution. The SF parameter recalibration could opt to consider the inclusion of spatial and peril correlation in the assessment process which can have a material impact to the capital estimation (Hillier and Dixon, 2020). The approach of recalibrating existing correlation estimates and adding new ones both at intra-territory and inter-territory values would follow a similar process to the recalibration of SF parameters described in the main document.

8.15. How could this approach have been implemented?: Currently there are matrices across different geographies, which relate the hazard intensity and frequency across CRESTA zones. This correlation could be explored across countries and across perils under a changing environment. However, this approach is rather complex, and at the same time there is a huge uncertainty on the calibration. In order to take into account all climate change-related uncertainties, the matrices may be too granular and lead to over parametrization and, thus, this approach may not yield accurate results.

Organisations which are members of the Technical Expert Network on Catastrophe Risks

Please see below the list of organisations with whom the members of the Technical Expert Network on Catastrophe Risks are affiliated. The inputs provided in the methodological paper is based on each individual member's expertise and contribution.

Achmea
AIR Worldwide
AON
AVIVA
AXA
Consorcio de Compensacion de Seguros
CoreLogic
EEA (European Environment Agency)
Generali
Guy Carpenter
HannoverRe
JBA
MRN (Mission Risques Naturels)
MunichRe
Nationale-Nederlanden
PERILS
RMS
SCOR
SwissRe
University of Cambridge
Willis Towers Watson

List of abbreviations

CAP - Common Agricultural Policy

CLIM - Climate state and Impact indicators published by the EEA

EEA - European Economic Area

EEA - European Environment Agency

EM-DAT - Emergency Events Database

ETC – Extra Tropical Storm

EU - European Union

GCMs - General Circulation Models

IPCC - Intergovernmental Panel on Climate Change

JRC - Joint Research Center

LoB - Line of Business

MPCI - Multiple Peril Crop Insurance

Nat Cat - Natural Catastrophe

NCA - National Competent Authority

NDBI - Non-Damage Business Interruption

PHI - Potential Hail Index

RCMs - Regional Climate Models

RCP - Representative Concentration Pathway

SCR - Solvency Capital Requirement

SDDI - Supply-Demand Drought Index

SF - Standard Formula

SRI – Standardized Runoff Index

TEG - EU Technical Expert Group on Sustainable Finance

WISC - Windstorm Information Service

WMO - World Meteorological Organization

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