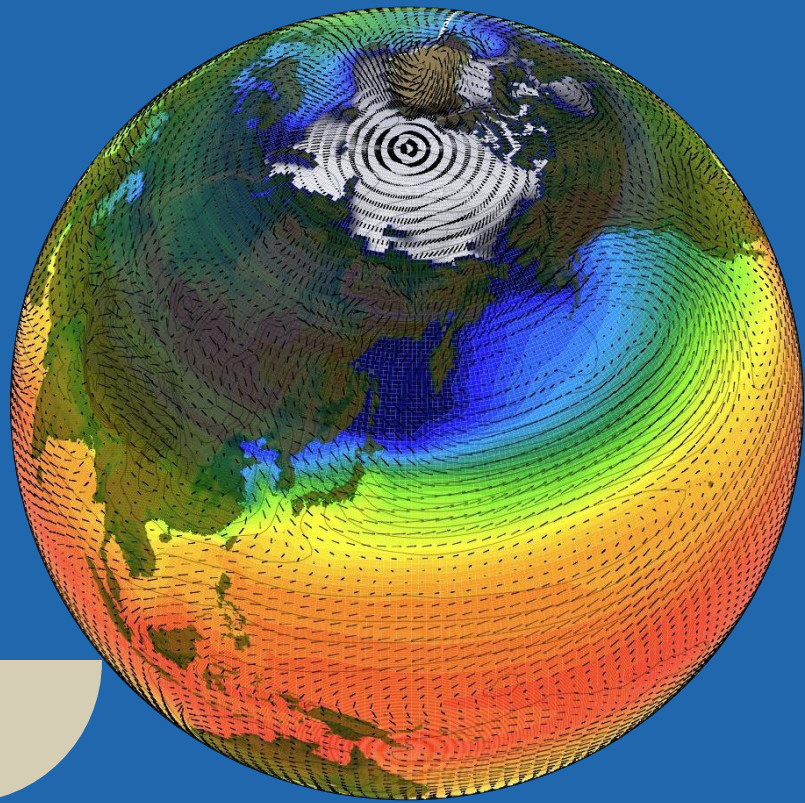
Global Climate Change Hazards Maps

Actuarial data science après-midi

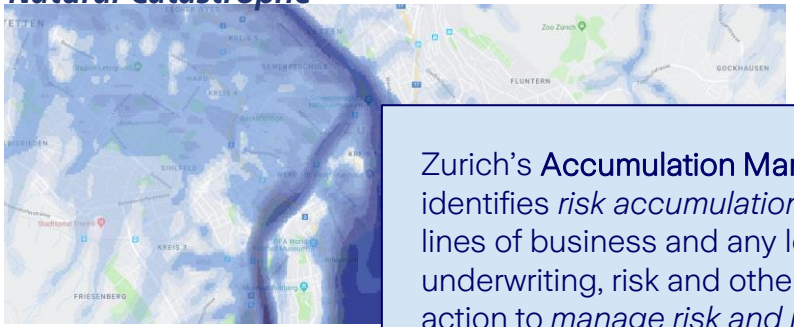


October 2nd 2024

Mathias Graf, Head of Cat R&D, Zurich Insurance

Zurich's Accumulation Management Vision

Natural Catastrophe



Man-made Catastrophe (Location specific)

Zurich's **Accumulation Management Vision** proactively identifies *risk accumulations* and generates *risk insights* across lines of business and any loss scenarios, equipping underwriting, risk and other functions to take appropriate action to *manage risk and improve profitability*.

We deliver risk insights to *customers* to help them *reach their full potential*.

This is achieved in a *timely, globally consistent and efficient* way, relying on *thought leadership, innovation and simple processes*.

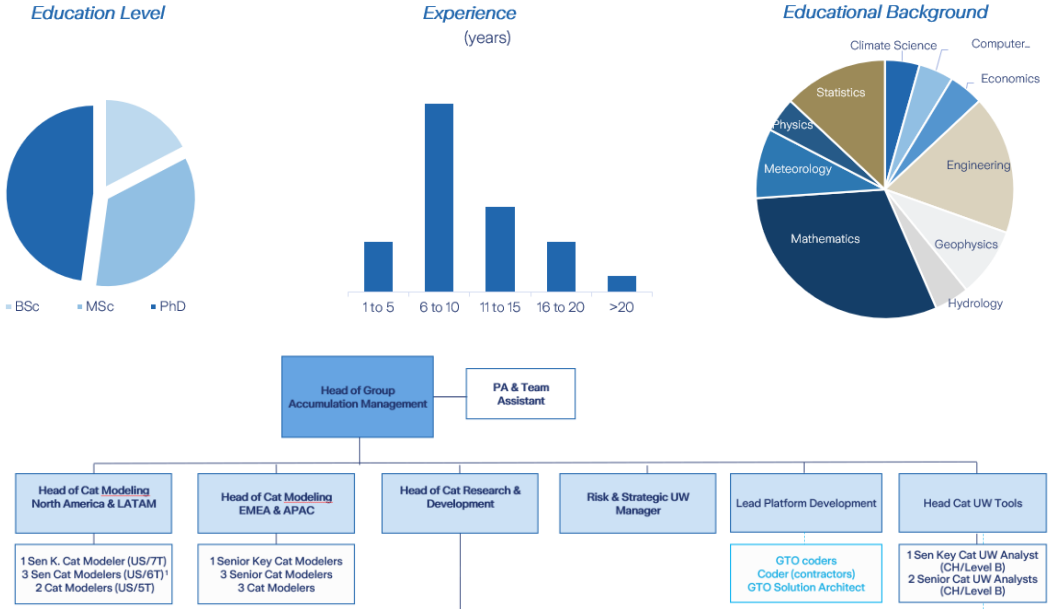
Cyber Catastrophe

Casualty Catastrophe

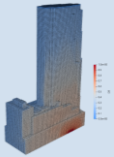
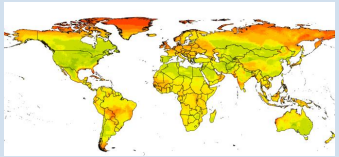
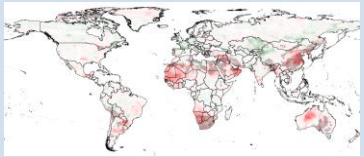
The Group Accumulation Management Team is highly specialized, experienced and has a global mandate for P&C business

Group Accumulation Management Team

- 32 professionals based in Switzerland, UK and US
- Diverse, interdisciplinary, specialized and highly qualified team
- Experienced in accumulation management with an average of about 10 years

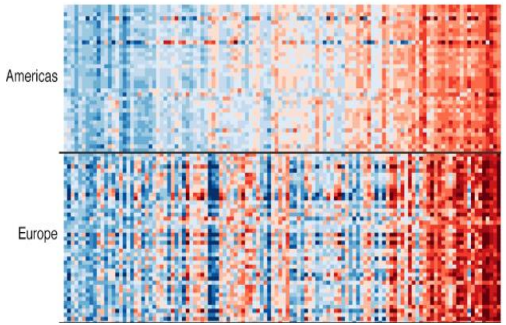


Artificial Intelligence & Machine Learning as a supercharger for risk insights

Vendor/Platform	U.S. Terrorism	Global hazard maps	Climate Change What-If Scenarios	Economic Exposure
Product visual				
Description	US terrorism model estimating the financial impact of truck bomb scenarios.	Global maps describing the hazard (e.g. windstorms, earthquakes) at different return periods.	Scenario (IPCC AR6) based analysis to estimate the impact of the climate change in terms of atmospheric perils.	Global exposure database describing buildings worldwide by cat modelling relevant features.
Development methodology	Neural Networks (GAN and feedforward NN).	Neural Network (Multi-layer Perceptron regressor).	Neural Network (Multi-layer Perceptron regressor).	K Neighbors Classifier and Neural Network (Multi-layer Perceptron regressor).
Data used	Open street maps, economic exposure data, Computational Fluid Dynamics (CFD) blast simulations arranged through Aon IF.	Climate reanalysis data, global earthquake activity data, land use data, topografic data, hazard values based on Zurich View of risk.	CMIP6 climate change data, land use data, topografic data, hazard values and model event sets based on Zurich View of risk.	Open Street Map data, GDP, light use, population density, Zurich's exposure data.
Models use today	Terrorism capacity /accumulation control in Cat Risk insights, portfolio accumulation assessment, event assessment.	Cat Risk Insights layers, pure premium/AAL calculator for cat pricing of simple or so far non-modelled risks.	Cat Risk Insights platform, quantification of monetary impact under climate change what-if scenarios.	Exposure data quality check and augmentation, input for terrorism model.

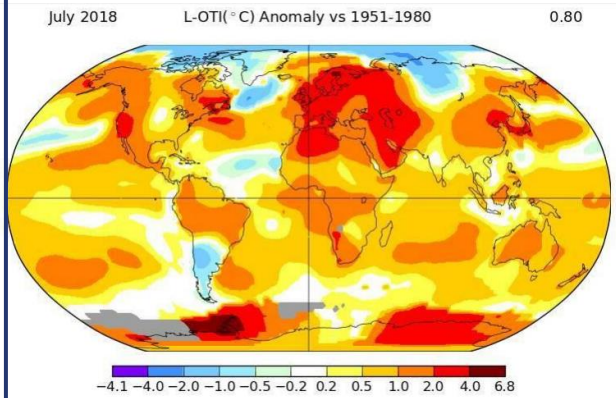
CLIMATE: WHAT ARE WE ALREADY OBSERVING TODAY?

The Warming Trend is Clear



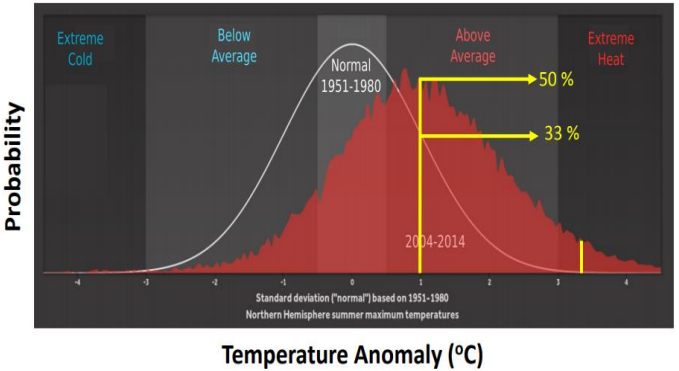
Source: #ShowYourStripes

+1°C average achieved but many places hotter



Source: Zurich Advisory Council for Catastrophes

Increasing Variability & Long-Tail risks grow



Source: Zurich Advisory Council for Catastrophes

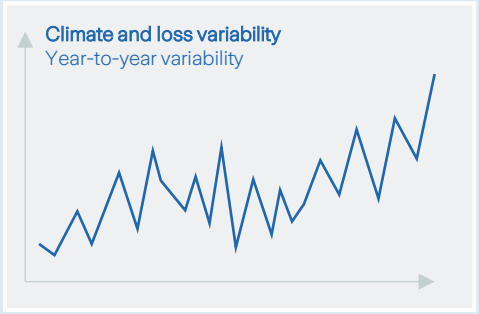
"According to RMS, cumulative Global Catastrophe losses of the last 30 years are in excess of $800bil. But what is terrifying is that **30% or $240 billion have occurred in the last 2 years**! Besides exposure developments **climate change is a contributor that we need to better understand.**"

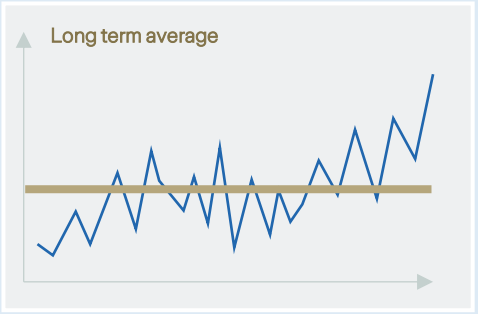
Natural variability and long-term trends

Analyzing hazard characteristics and scenarios helps us to **better understand** both our **current** and our **potential future risk.** Bringing historical data sets and future projections together allows us to better distinguish between natural variability and long-term trends.

Bottom-up: What do we see in our data so far?

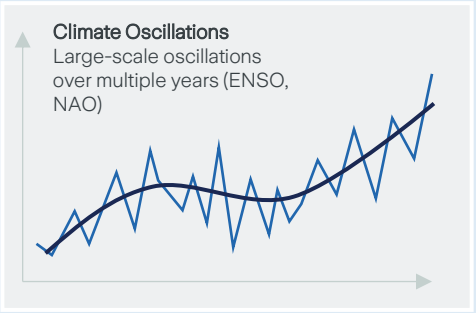
There is a risk that losses systematically exceed expected modelled numbers, as the model calibration is based on historical claims and events; and does not fully account for the **1.2° temperature change** that has already happened.

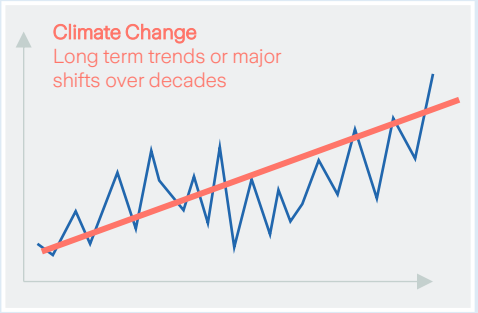




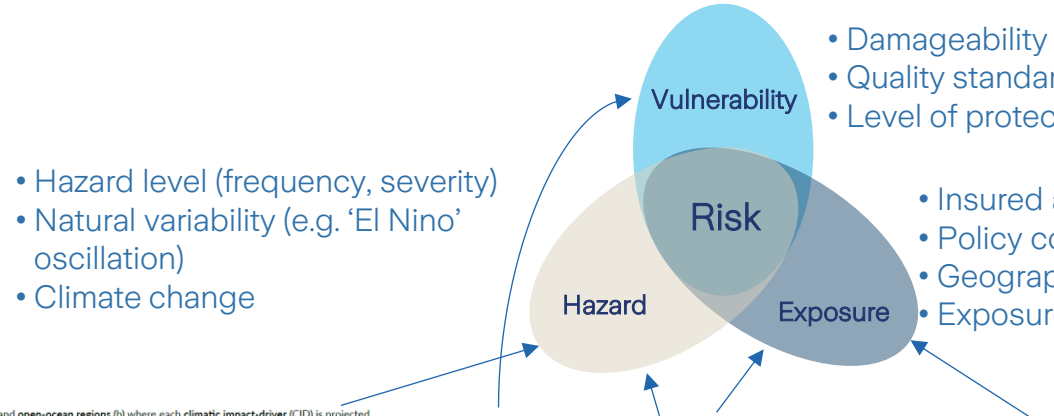
Top-down: What can we possibly expect next?

According to the IPCC, the frequency, the intensity, and the geographical distribution of events will **continue to shift**. Combining climate model data with our internal models enables us build tailored scenarios for our portfolios as a **basis for decision-making**.





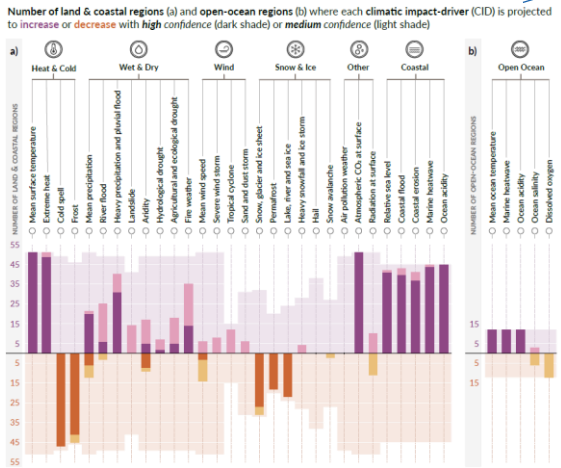
Accumulation risk is driven by hazard, vulnerability and exposure and is set to increase due to current global mega trends



- Damageability
- Quality standard (e.g. building codes)
- Level of protection

- Hazard level (frequency, severity)
- Natural variability (e.g. 'El Nino' oscillation)
- Climate change

- Insured assets (e.g. Buildings, Business Interruption)
- Policy conditions
- Geographic distribution
- Exposure data quality



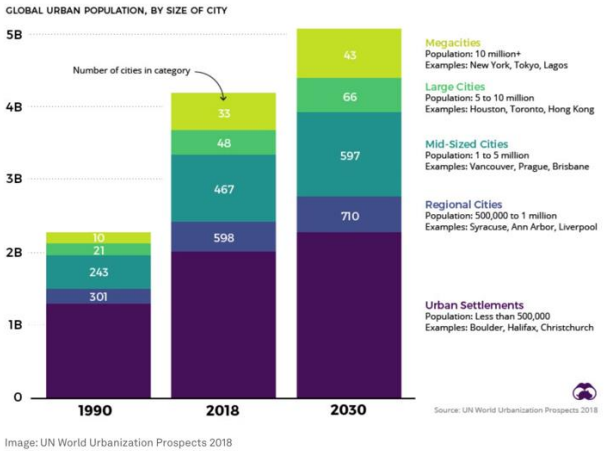
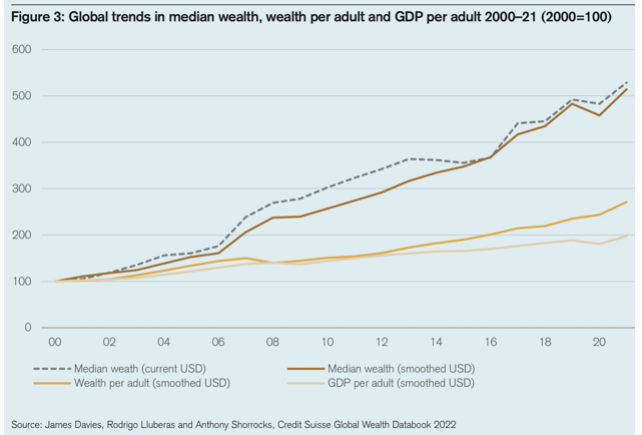


Image: UN World Urbanization Prospects 2018



Source: James Davies, Rodrigo Lluberas and Anthony Shorrocks, Credit Suisse Global Wealth Databook 2022

Climate Change impact assessment - Risks & Opportunities

	Main Focus	Risks	Opportunities
Short Term (1 to 3 years)	Pricing & Capital	• Incorrect stationary climate conditions built into models • Under (or over-) pricing and planning of risk • Insufficient reinsurance or capital	• Enhanced risk view taking climate trends into account • More accurate pricing and planning • Improved reinsurance and capital structure
Medium Term (3 to 10 years)	Underwriting Strategy	• Underwriting strategy informed by incorrect stationary climate conditions • Unbalanced risk-adjusted portfolio impacting profitability • Unexpected losses leading to rushed portfolio action • Impacts on supply chain (e.g. water shortage) • Climate change adaption (e.g. building codes)	• Well balanced risk-adjusted portfolio meeting profitability targets • Fuel product innovation leading to market opportunities
Long Term (10 to 30 years)	Underwriting, ZRS & Investments	• Underwriting and investment strategy informed by incorrect stationary climate conditions • Unbalanced risk-adjusted portfolio impacting profitability	• Well balanced risk-adjusted portfolio meeting profitability targets • Consulting of Zurich's customers • Fuel product innovation leading to market opportunities

Starting point: Climate Change Impact Assessment by Zurich Advisory Council for Catastrophes (ACC)

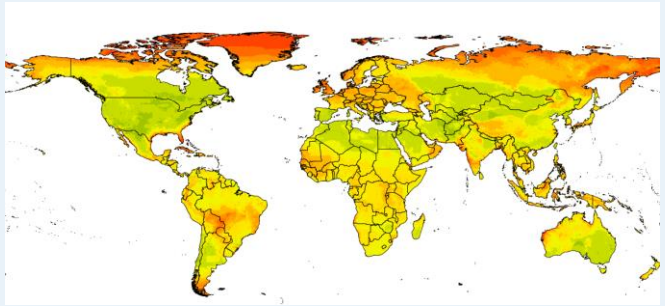
Phenomenon	Metric	Benchmark Period	Changes			
			To the Present	1.5°C	2°C	>2°C
Heat Waves	Land fraction warmer than prior record	1850-1920	10-20% (High)	50-60% (Med-High)	80% (Med/High)	>80% (Med-High)
Heat Stress	% Days for external labour	1881-1910	5-16% (High)	20-30% (High)	30-40% (High)	>50% (Med-High)
Drought	Proportion of land where drought exceeds typical historic levels	1916-2016	Increasing trend (High) Large increasing trends emerging in some regions (High)	Further Increases (Med-High)	Large increases (Med-High	In some regions unrecorded drought levels become the norm (Med-High)
Tropical Cyclone	Frequency	Since 1975	Nil global (High)	Small global decrease (Med-High)	Small additional global decrease (Med-High)	Small additional global decrease (Med- Low)
	Maximum intensity	As above	Nil global from 1975-2010 (High)	<10% (Med-High)	10-20% (Med-High)	5-10% for each 1oC (Med-High)
	Global proportion Cat 4-5	As above	Substantial increase globally – variable by region (High)	Small increase from 2010-2015 (Med)	Small increase from 2010-2015 (Low)	Small increase from 2010-2015 (Low)
Sea Level Rise	Global Mean	1990	~10 cm (High)	~20 cm (High)	~1 m (Med-High)	Rapid increase to several meters or higher (Med-High)
	Regional (includes land movement)	Annual changes	-2 to10 mm/y (High)	Highly variable increases (High)	Highly variable increases (High)	Highly variable increases (High)
Tropical Cyclone Surge	Probability of major storm	1980-2000 for future changes	Probability has increased 2 times over 20th century (Med-High)	Further increase (Med)	Further increase (Med)	Increase 2-20 times to 2100 with potential for unheard of surge levels (Med-Low)
Extreme Rainfall	Single event rainfall	Pre 1970	10-15% (High)	15-20% (High)	20-30% (High)	10-15% per °C (High)
	Percentage of events >historical 99% level	1976-2005	Regionally variable generally slightly upward	Regionally variable 7-8% (Med-High)	Regionally variable 13-15% (Med-High)	Potentially 300% increase in 99% level occurrences (US example) Low)
	Size of extreme rain system	1980-2010	No info	No info	No info	2-20% increase (US example) (Med)
Tropical Cyclone Rainfall	Return Period of Extreme Rain	2000 y return period rainfall 1980-2000	~300 y (High)	Increase (Med)	Increase (Med)	~100 y (Med-Low)
Large Hail	Frequency of hail >2.5 cm diameter	1980-2010	Increasing trend Europe, little change in US and Australia (High)	No info	No info	Regionally and seasonally dependent substantial increase (Med)

Products

Two different types of outputs

Climate Change Hazard Maps

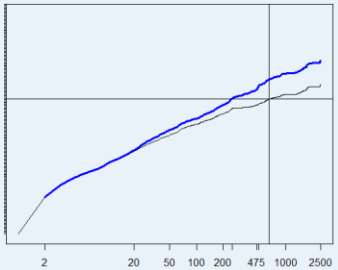
Development of the climate change hazard maps and integration into CRI



- Wind
- Storm surge
- Flood
- Hail & Tornado
- Secondary products (temperature, precipitation, drought index, heat stress)

Climate Change Cat model integration

Development of a future climate change risk view and integration in existing Cat models and GAM workflow.

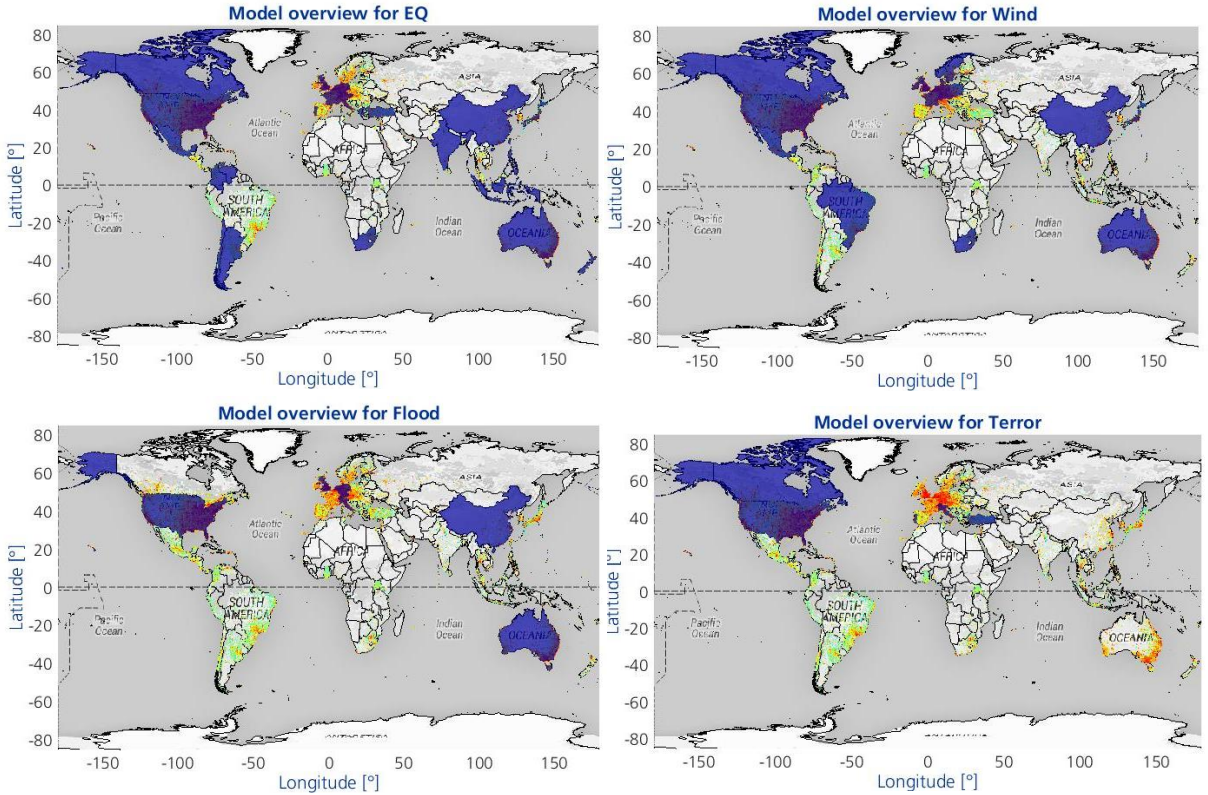


- Tropical Cyclone (US, AU, JP, CN)
- Flood (EU, US)
- Storm surge (US)
- Severe convective storm (EU, US)

Zurich's Cat Models are covering the majority of all relevant peril regions.

- The majority of the main peril regions is covered by a cat model.
- There are still gaps in the risk landscape.
- Zurich View projects are continuously conducted to derive our own View of Risk and to close further gaps.

- Global consistence data sets like reanalysis data ERA5 have a too crude resolution, too short time series and potentially a mode bias and can not be used to create global consistent hazard maps.



Leveraging Neural Networks to develop global consistent Hazard Maps for Cat Risk Insights

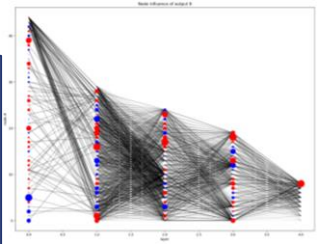
A global consistent earthquake, wind, storm surge, hail and tornado hazard map is delivered and is available in the Cat Risk Insight platform.

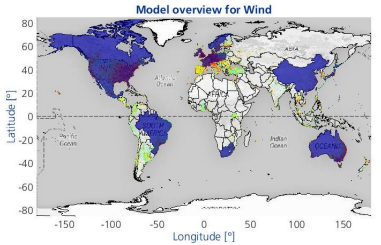
Reflecting the insights of all Zurich Views, combined with public available global consistent data, a Neural network is used to spatial extrapolate insights from modelled regions to non modelled regions.

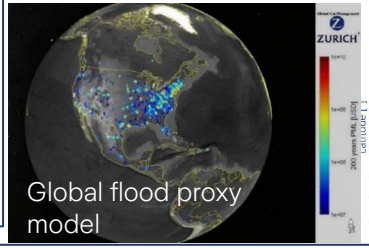
For pricing purpose, a AAL calculator is developed based on the global hazard maps.

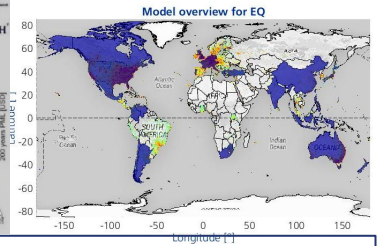
The AAL calculator is calibrated to reflect on a portfolio level the Zurich View, ensuring that there is no bias between the portfolio accumulation risk assessment and the single location risk assessment.

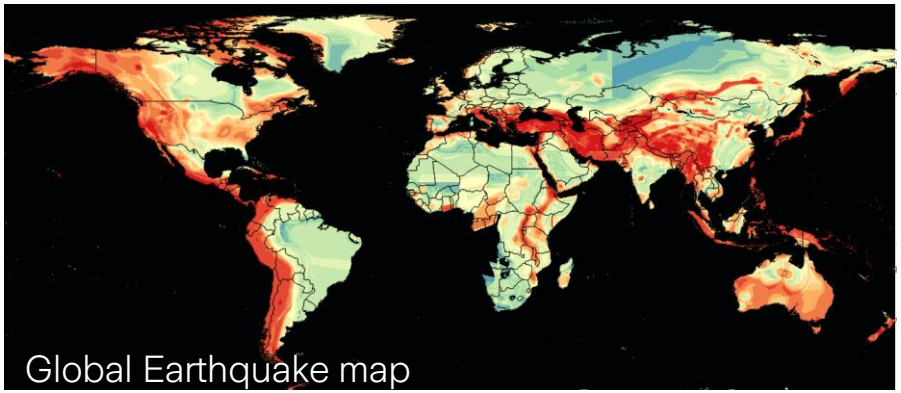
A global flood, wind and earthquake proxy in-house model is developed using the global hazard maps, the calculation engine of the AAL calculator and the correlation length of typical cat events, facilitating the estimation of PML for any region on the globe.

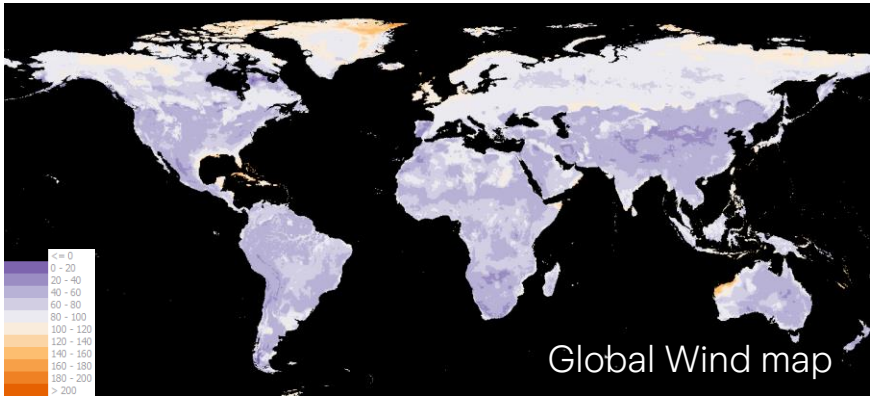




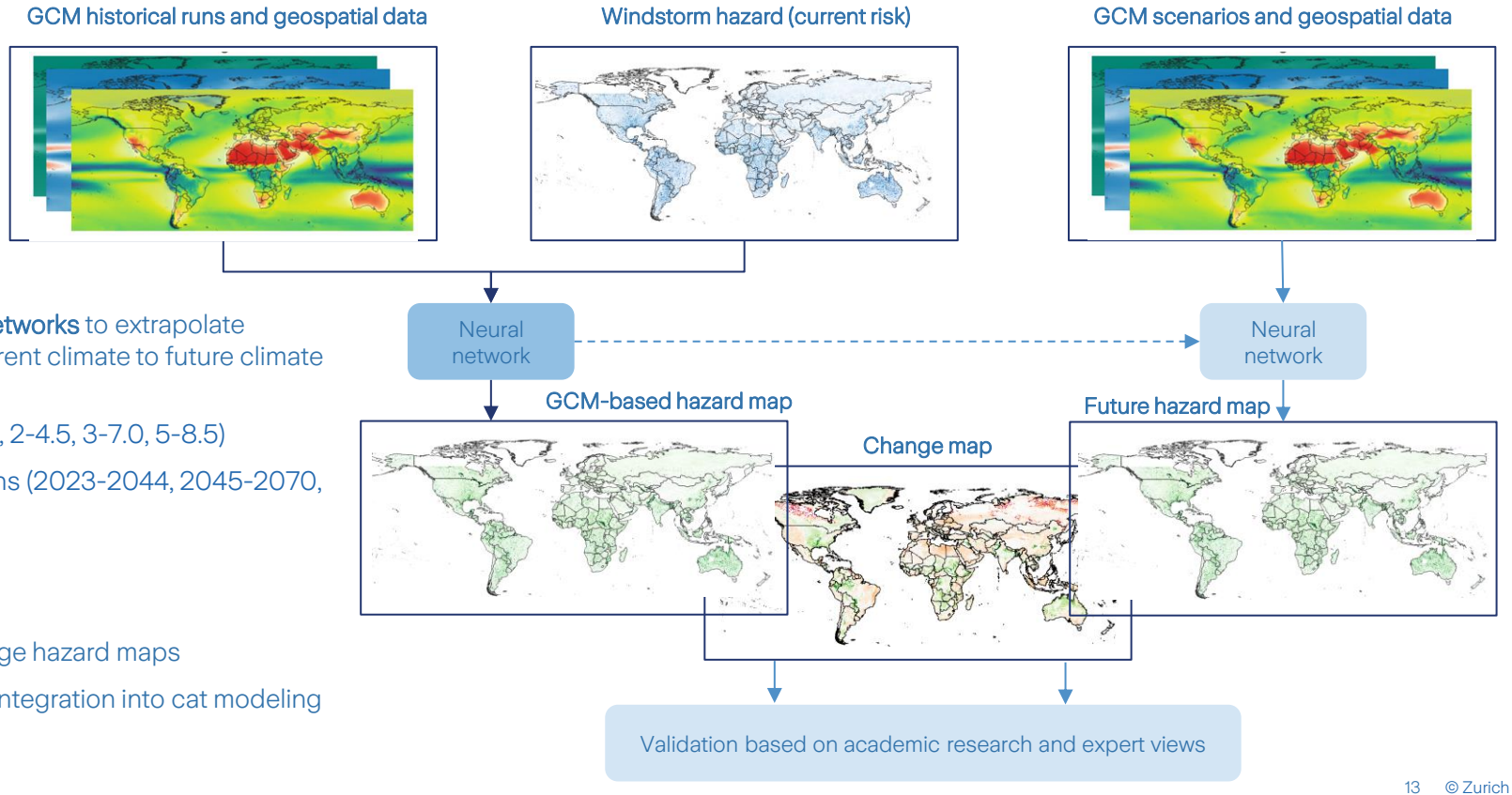








Developing future hazard maps for climate change scenarios based on General Circulation Models (GCMs), hazard maps and neural networks



We use **neural networks** to extrapolate insights from current climate to future climate scenarios

- 4 SSPs (1-2.6, 2-4.5, 3-7.0, 5-8.5)
- 3 time horizons (2023-2044, 2045-2070, 2071-2100)

Products

- Climate change hazard maps
- Quantitative integration into cat modeling

CatRisk Insights Platform – A key asset built by Group Accumulation Management

~100 million hits in 2023!

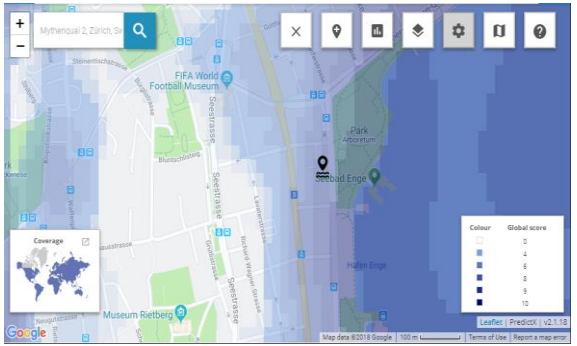
12 Nat Cat perils deployed

- Zurich Earthquake
- Zurich Flood (incl. climate change by year-end)
- Zurich Windstorm (incl. climate change)
- Zurich Hailstorm
- Zurich Tornado
- Zurich Storm Surge (incl. climate change)
- Zurich Aircraft Impact
- Zurich Netherlands Dam Breakage
- Swiss Re Wildfire
- Swiss Re Lightning
- Swiss Re Tsunami
- Swiss Re Volcano

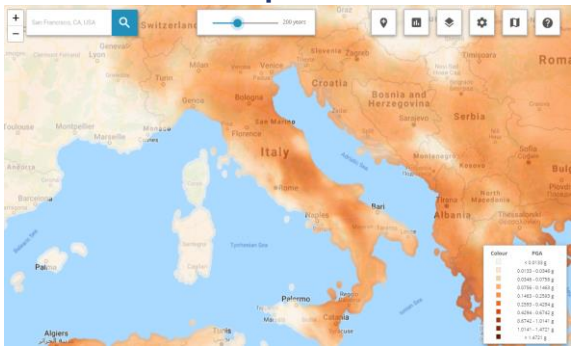
Cat Risk Insights (zurich.com)

- Global coverage
- Various measures:
  - Hazard data for risk selection
  - Notional data for accumulation management
  - Global scores for pricing purposes
- Web Interface (maps)
- Automated retrieval of data and integration into Zurich applications (API):
  - NEO, GPP, REDS, GREW, Insight 360, MyZurich, Zorba, US Policycenter, Perils Risk Score (Malaysia), SME Tower
  - Being added: Morpheus, Germany Impulse Project
- Benefits:
  - Facilitates location-based hazard risk assessment and risk selection
  - Supports portfolio optimization and pro-active accumulation management
  - Enables consistent and adequate Cat pricing across regions

Flood (Pluvial and Fluvial) Risk



Earthquake Risk



GAM has the experience, skill and infrastructure to develop and deploy global hazard layers, but not the bandwidth to replace vendors

ZURICH

Deployed
Developed
In development

Global current risk hazard layers

2019	2020	2021	2022	2023	2024
Wind	Aircraft impact	Tornado	Storm surge	Wildfire	
Earthquake	Dam breakage	Hail		Hail V2	

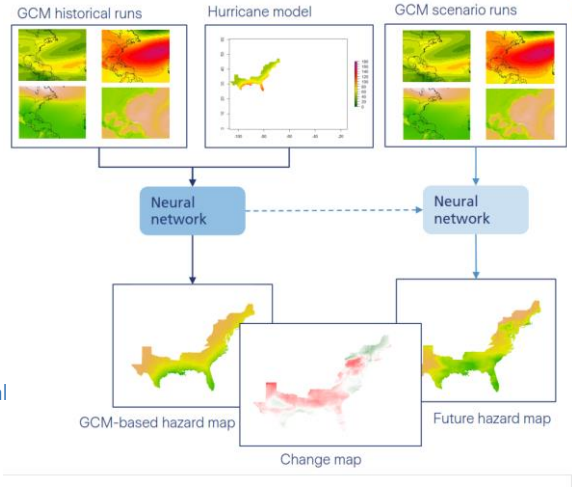
Global climate change hazard layers

2022	2023	2024
Wind	Flood	Tornado
Storm surge	Precipitation	Hail
Sea level rise		

Global current and climate change hazard layers

- 5+ years of experience and technical skills in developing global hazard layers within the Cat R&D team.
- 12+ internal current and climate change global hazard layers developed.
- Leveraging the purpose build Cat R&D IT infrastructure.
- Using AI to extrapolate the knowledge/ information of modelled regions to a global scope.
- Using AI for temporal extrapolation to assess climate change impacts.
- Hazard layers are consistent with the Zurich View for portfolio accumulation management and account pricing, which facilitates one consistent risk view for UW risk selection, pricing, customer services, portfolio modelling, reinsurance, capital model, etc…
- The consistency with the Zurich View facilitates the recalibration of existing cat models to quantify the financial impact of different climate change scenarios.

AI methodology for global hazard map development



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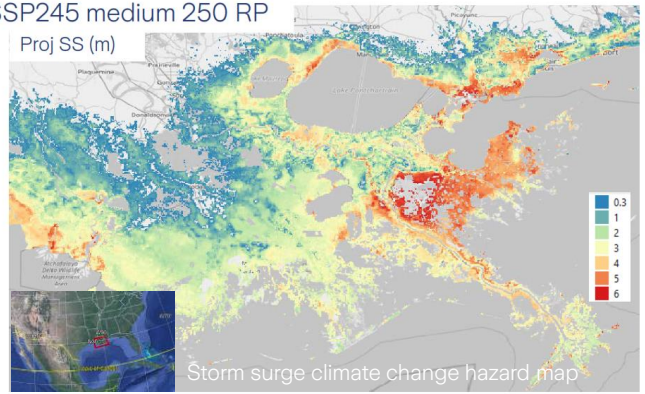


Cat Model components

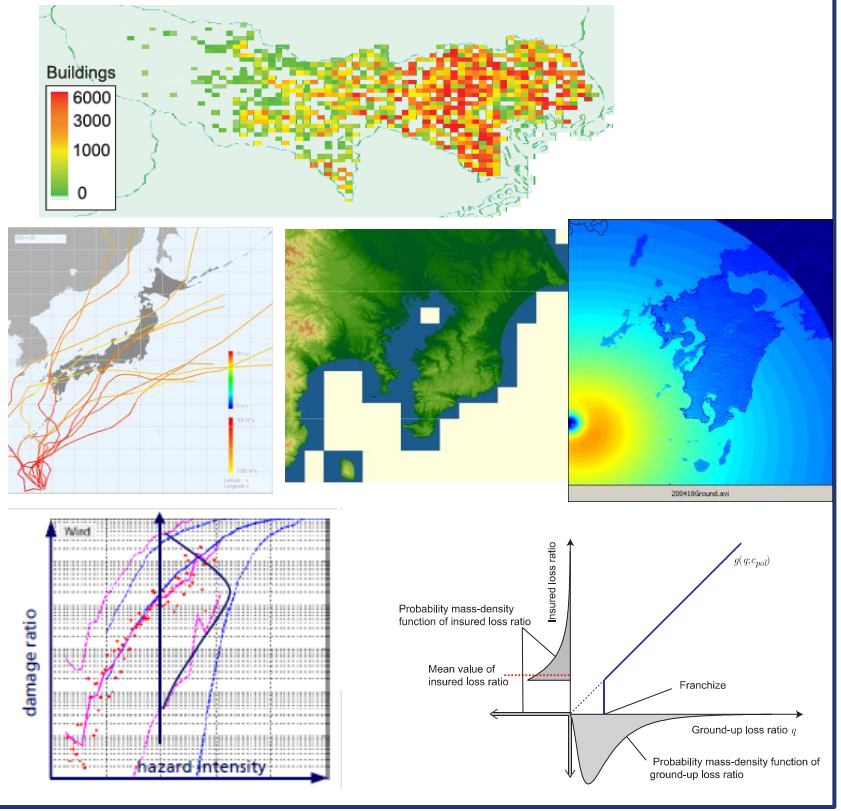
Exposure

Hazard model

Vulnerability model

Financial model

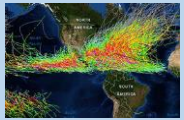
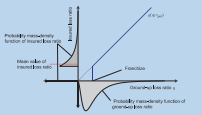
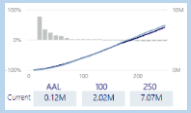
- **Exposure**: The way the exposure can be reflected, what can be reflected in terms of occupancy classes and construction, geo-coding quality etc.
- **Hazard**: frequency, severity and spatial correlation of the hazard (e.g. rate of events, the frequency model (Poisson vs. cluster assumptions), event generation (variation of history, numerical simulation, discretization of hazard) footprint generation, site specific modification factors (soil response, surface roughness))
- **Vulnerability**: Set of functions mapping an intensity measure like wind speed or ground shaking into financial loss. Vulnerability functions are specific to exposure types and geographic regions.
- **Financial model**: Ability to reflect the structure of participations, deductibles, limits and reinsurance on an account.



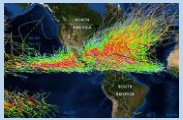
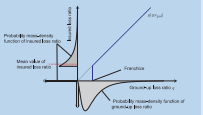
Climate Change - Financial view

Method

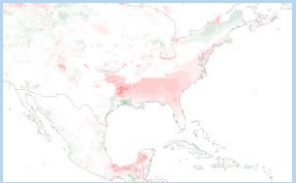
Cat Models (RMS, Verisk, KatRisk)

- Exposure 
- Hazard 
- Vulnerability 
- Financials 
- Current metrics 

Cat Models with climate change

- Exposure 
- Hazard 
- Vulnerability 
- Financials 
- Scenario metrics 

1. Connect climate model data with our cat models through neural networks to estimate the change in **hazard** with high spatial diversification



2. Adjust frequencies (1), severities (2), and uncertainties (3) in the stochastic event set according to the expected hazard change

	1	2	3
Event ID	Rate	Mean Loss	Std
2007554	1.80E-05	2.28E+07	1.68E+07
2006049	1.19E-06	2.30E+07	1.72E+07
2007555	1.47E-06	2.30E+07	1.71E+07
2007540	1.47E-06	2.36E+07	1.72E+07
2007762	1.01E-04	2.36E+07	1.60E+07
2006027	1.29E-07	2.38E+07	1.75E+07
2006048	5.07E-07	2.38E+07	1.75E+07
2007553	1.47E-06	2.38E+07	1.71E+07
2007757	2.89E-05	2.40E+07	1.61E+07
2007893	1.35E-06	2.43E+07	1.54E+07
2007891	1.35E-06	2.43E+07	1.56E+07
2007519	7.22E-07	2.44E+07	1.72E+07

3. Assess financial impact of climate change scenarios

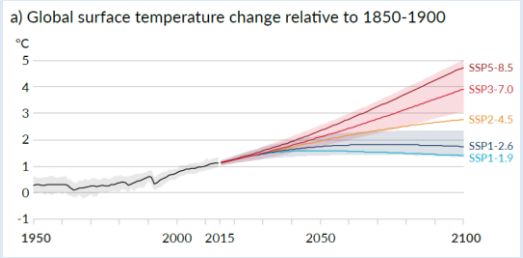
Impact assessment beyond the pure hazard view through consideration of:

- ✓ Policy conditions
- ✓ Treaties and reinsurance cessions
- ✓ Spatial patterns in estimated hazard changes
- ✓ Spatial correlation
- ✓ Inter- and cross-peril correlation
- ✓ Model uncertainty
- ✓ Scenario uncertainty

Climate Change - Example on financial view

Portfolio level

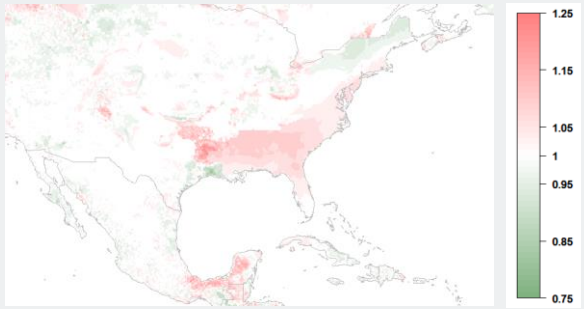
Scenarios by IPCC and its contributors



ipcc INTERGOVERNMENTAL PANEL ON climate change

WCRP CMIP6 World Climate Research Programme

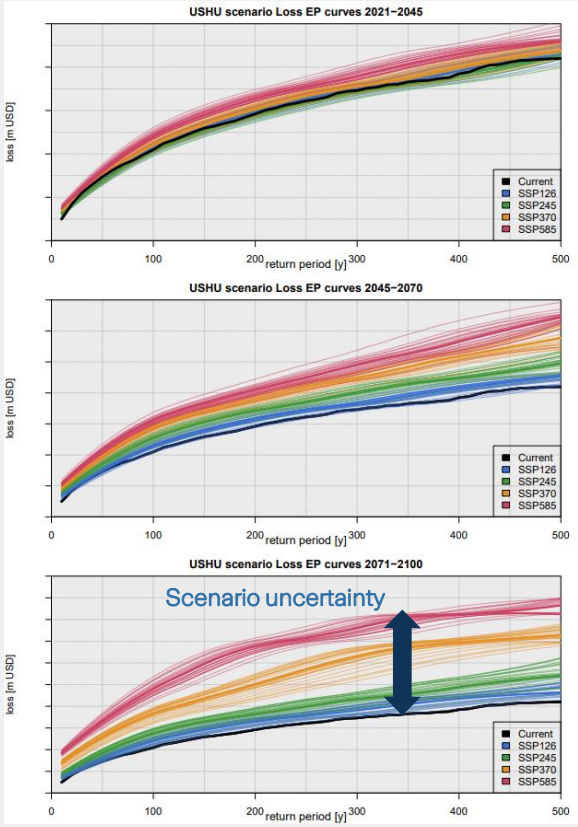
Map of potential hazard change



Scenario implications on group, portfolio, account and location level

Estimated changes in mUSD for mean projected 2021-2045 conditions			
Scenario	**AAL**	**250 PML**	**2000 PML**
Current	X	Y	Z
SSP126	-1%	1%	3%
SSP245	-4%	-1%	1%
SSP370	4%	3%	4%
SSP585	21%	10%	10%

What-if EP-curves



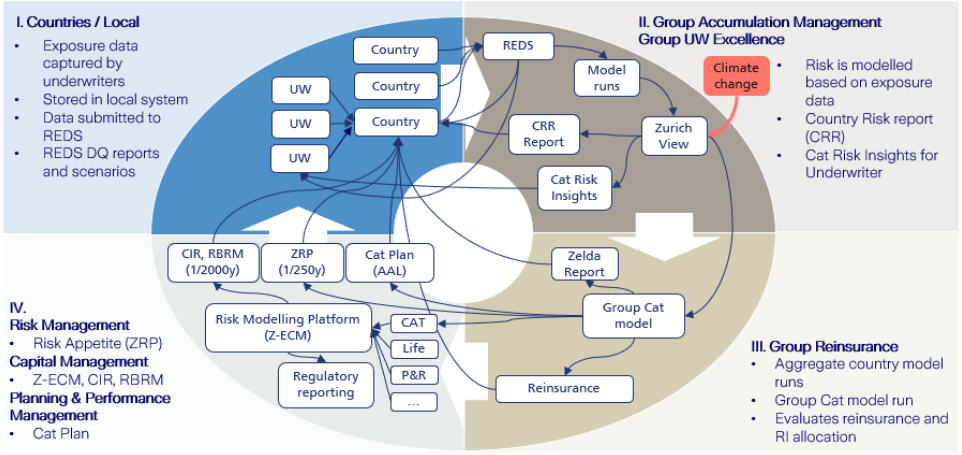
INTERNAL USE ONLY

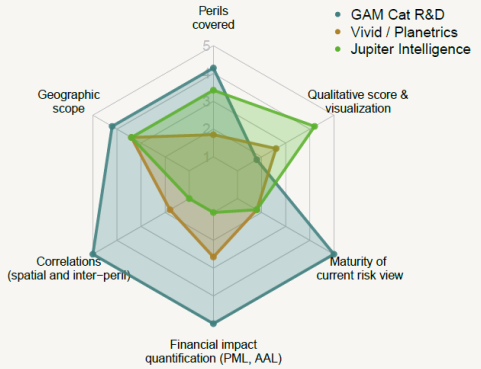
Financial view

Integration in our internal cat risk management cycle

Unlike the numerous data suppliers and consulting firms, we can go **beyond the pure hazard view**:

- We have the capabilities to incorporate the new IPCC scenarios into our cat modeling workflow. This quantified view on scenario impacts enables to **put potential impacts into perspective**., and therefore serves as a **basis for informed discussions.**
- We can reflect potential risk changes not only on a temporal level but also on a (high resolution) geographical level
- The approach also allows for a direct integration of climate change scenarios in the Zurich Nat Cat management cycle.





A comparison with external data suppliers and consulting firms showed that most of them focus on hazard and data visualization. We mainly differentiate from them in the following areas:

- The prioritization of peril regions and the analyses are tailored to our needs
- We can use our own claims calibrated Zurich view of risk view as a baseline
- All modelled financial metrics (e.g. AALs, PMLs) available for current risk as well as for climate scenarios
- Geographic correlation is captured through 1.9 million events reflecting the geographic diversification

Use cases

Climate change works help to better understand both current and future risks

Underwriting	Support underwriters in risk selection and portfolio managers in proactive decision-making
Pricing	Ensure we charge the right risk premium. Avoid reliance on hazard and claims data that don’t reflect current conditions
Accumulation Management	Spatial and temporal correlations are explicitly considered and can be fed into the Capital Model
Reinsurance	Ensure we purchase the right coverage. Competitive advantage through more granular, more accurate, and regularly updated risk view.
Reporting and disclosure	A one-stop-shop for climate change-related physical risk assessment support BU’s and CC in efficiently and consistently responding to requests
Investment management	Assess long term risk scenarios for various investment portfolios
Underwriting strategy	Potential shifts in geographical distribution of hazard can be anticipated and considered in portfolio management and underwriting strategy
Customers	Help our customers through Risk Engineering Services, and answer questions that we regularly receive.

Climate Change - Summary

- Up to now, results are in line with both academic findings and short-term trend extrapolations
- Unique capability of financial modeling and integration into Zurich view enables us to quantify the climate change impacts, and to put it into perspective.
- Less dependency from third-party data suppliers and less guess-work
- Short term impact is small compared to natural variability. Long term impact is potentially big but subject to large uncertainties

Input

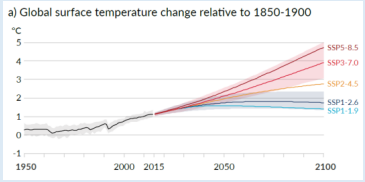
Internal expertise

The Group Accumulation Management team has a broad knowledge on Nat Cat risk modeling, as well as on the Nat Cat risk management measures on Group level.

Models and current risk view

A well-established internal workflow for modeling and managing Nat Cat risks, and a comprehensive understanding of our current risk builds a strong foundation for modeling and assessing future hazard scenarios.

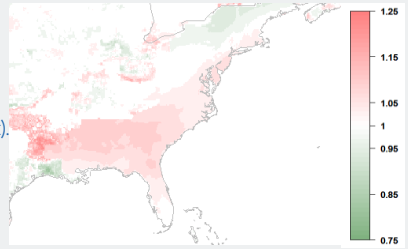
IPCC climate change scenarios



Output

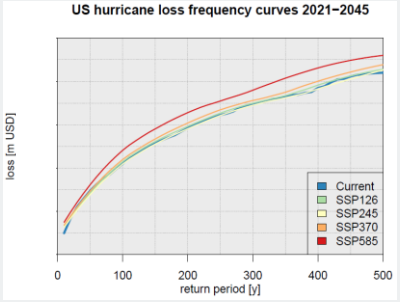
Maps

Analyses on how hazard is expected to change under the IPCC scenarios result in high resolution hazard maps for each scenario (illustrative example for US hurricane on the right).



Loss probability curves

The estimated hazard change for each scenario builds the basis for calculating loss probability curves on different aggregation levels (BU, portfolio level, account level).



Quantified scenario impacts

Estimated financial impact of the IPCC scenarios on group level. The integration of climate change scenarios in our Nat Cat model landscape allows us to also implement the changes in the group model.

Use cases

Understanding current risk

Keep risk view updated ("Zurich view of risk") to ensure the current hazard situation is appropriately reflected in our models.

Understanding future risk scenarios

The full integration of climate change in our Nat Cat model landscape allows us to conduct "what-if"-analyses for various scenarios and time horizons, and to quantify potential impacts. This builds a basis for and informed discussion.

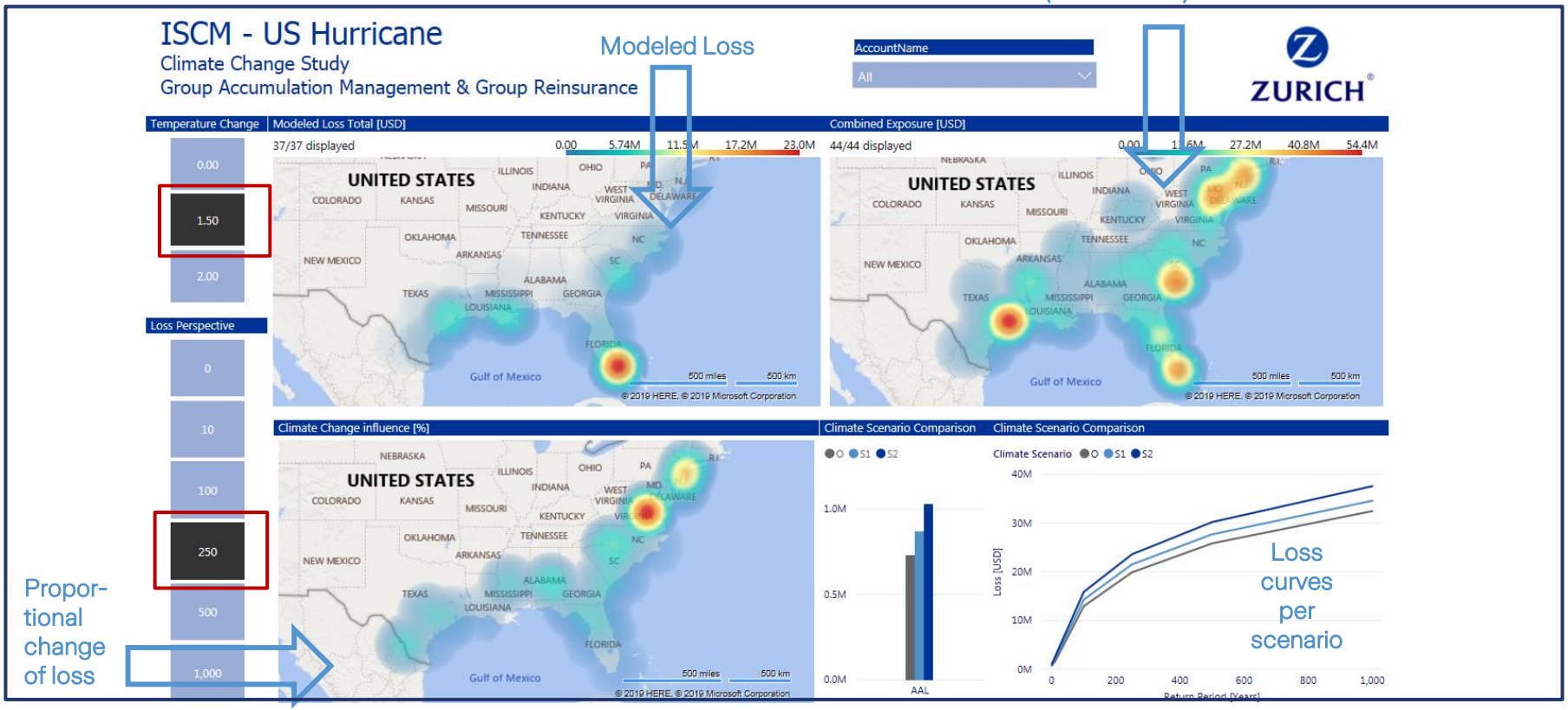
Put climate change into perspective

A quantified view on potential climate change impacts enables assessing how the impact of different climate change scenarios compare to other risks.

Climate Change Impact Assessment

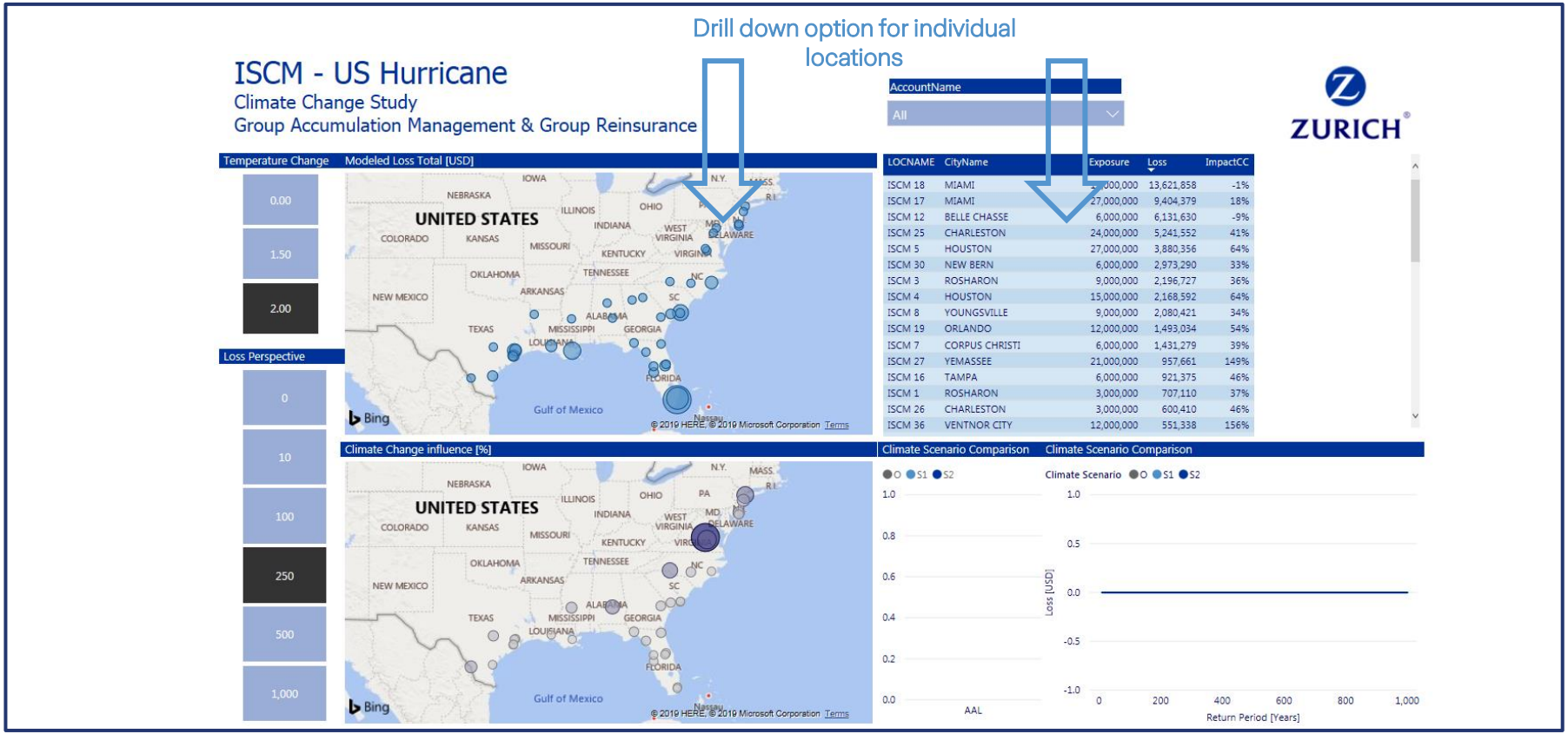
US Hurricane example: Notional Portfolio

Exposure distribution (sum insured)



Climate Change Impact Assessment

US Hurricane example: Location overview



Climate change business impact and opportunities

Pricing
- Understanding the additional climate change risk.
- How to integrate climate change impact, e.g. gradual increase.
- What does the competition do.

Portfolio management
- How to adapt the portfolio due to climate change
- Move out of uninsurable peril regions & incentivize customers resilience
- Portfolio composition for diversification

New Products
- New risk is an opportunity
- Identification of new opportunities, e.g. hurricane policies in California or Portugal.
- Completely new products, e.g. BI due to heat wave.
- Services for Resilience

Risk Selection
- Understanding change of risk over time and space.
- Understanding change in exposure development.
- Cherry-picking, e.g. Insuring only buildings with new building codes

Capital cost
- Climate change is potentially global correlated
- Better diversification thru portfolio management
- More reinsurance
- Risk appetite Cat vs Non-Cat

Parametric Products
- Can parametric trigger products being used to cover insurance gaps?
- Parametric trigger products are easy to understand and cost efficient in administration and claims handling.

May 20.