Measuring the Climate Physical Risk:
Business Exposure and Validation Perspective

Alexander Andrianov, Mehdi Rezaeianzadeh, Gain Boonvanich, Yang Yang, Barbara Wortham, Zane Martin, Paul Wyer

PwC US Sustainability Climate Risk Team

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pwc



Identify assets at-risk from extreme weather perils

$1.7 - 3.1 trillion

That’s how much the world’s largest companies face in global climate risks by 2050

More frequent and severe wildfires, floods and heat waves underscore the need for businesses to become more resilient to climate physical risks that are affecting building, contents, inventories, and supply chain. Climate risks can be growth opportunities for businesses that develop strategies that can turn potential challenges into pathways for innovation and transformation. Embedding resilience into business strategy enables companies to anticipate climate-related risks, protect assets and enhance performance and quality.

Source: World Economic Forum, 2023.



Helping companies in assessing and getting ahead of climate risks



Reporting facilitation

Support companies' alignment and reporting of government-mandated disclosures related to climate risks and their potential financial impacts.



Supply chain analysis

Prepare for the possible effects of climate on your clients' suppliers by adopting a future-oriented, holistic, and global view of their supply chain.



Strategy optimization

Develop **mitigation and adaptation** strategies throughout your clients' network of assets in advance of any climate-influenced adverse weather events.



Investment opportunities

Assist companies in embedding sustainability strategy throughout investment strategies and risk management processes, in order to mitigate risk and take advantage of potential new opportunities.

Executive Summary

There has been an observable rise in the frequency and severity of weather hazards that are likely attributable to global climate change. This poses a risk to businesses across the globe stemming from building and content damage and supply chain disruptions.





To address this, PwC developed a suite of models to generate global maps representing climate-related hazard variability. These models use various global climate models' and observational data. Climate science plays a pivotal role in driving reliable risk evaluation, enabling businesses to plan and mitigate climate risks.

Perils Overview



Flood*

Flood is an overflow of water on a normally dry area.

Global coverage at 1km resolution
Depth of flood at various return periods



Hail

Hail is solid precipitation associated with cumulonimbus clouds.

Global coverage at 5km resolution
Probability of hail



Wildfire

Wildfire is an unplanned fire that burns in a natural area.

Global coverage at 2.5km resolution
Expected burn area in acres



Drought

Drought considers local precipitation and evapotranspiration

Global coverage at 50km resolution
Moderate, severe, and extreme levels



Wind Gust

Extreme wind events associated with events like thunderstorms, etc.

Global coverage at 25km resolution
Max speed of three-second sustained wind gust



Heat Stress

Combination of temperature and humidity relating to human capacity to perform labor.

Global coverage at 50km resolution
Frequency of wet bulb temperature thresholds



Tropical Cyclone

A tropical cyclone is a large rotating storm with winds more than 118 kph

Global coverage at 5km resolution
Category 0 to Category 5 events



Tornado

A tornado is a violently rotating column of air from storm to ground.

Global coverage at 75km resolution
Frequency at events of Fujita scale F0 – F5



Extreme Heat

Daily maximum temperature thresholds.

Global coverage at 50km resolution
Number of days at a particular temperature



Storm Surge

Storm surge is abnormal rise of water generated by tropical cyclones

US East & Gulf of Mexico, 500-meter resolution
Where storm surge occurs



Sea Level Rise

Sea level relative to global shorelines, causing loss of land.

Global coverage at 30-meter resolution
Where Sea Level Rise occurs



Extreme Cold

Daily minimum temperature thresholds.

Global coverage at 50km resolution
Number of days at a particular temperature

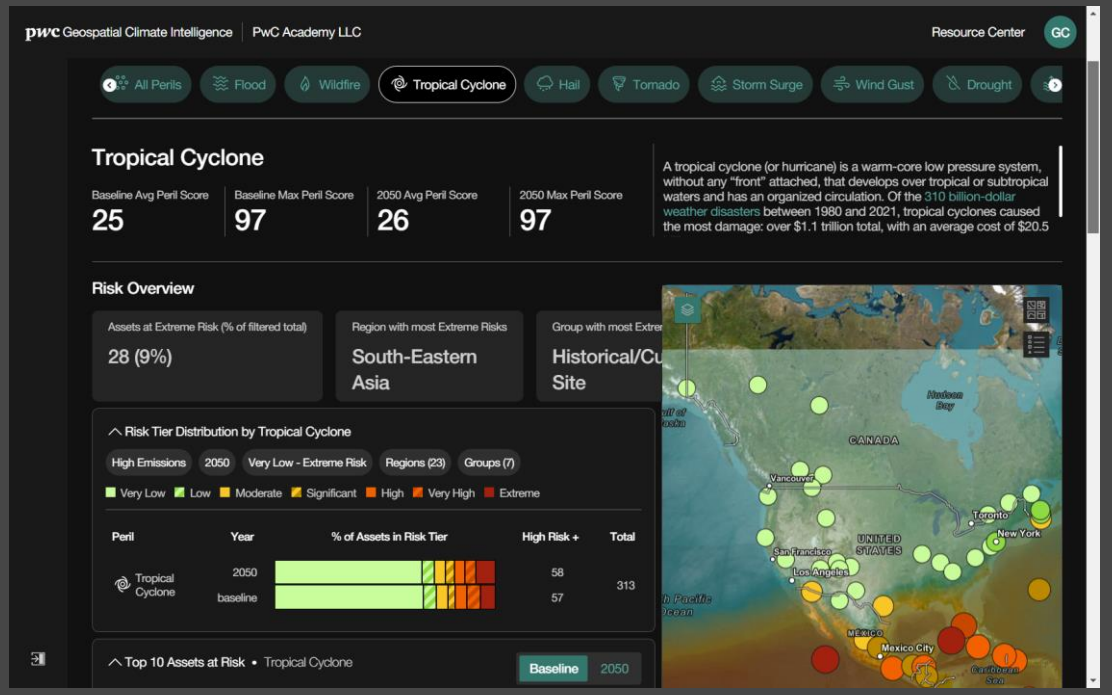
Sample visualizations and outputs



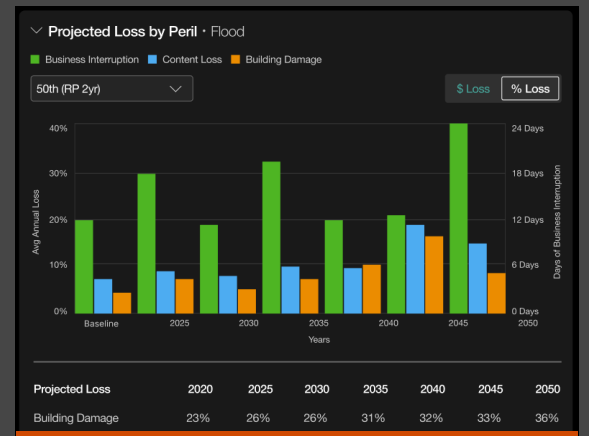
New Orleans, Current



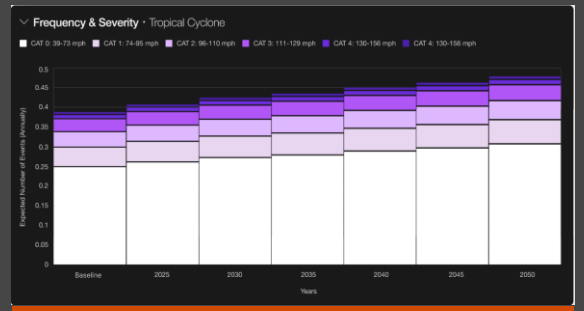
New Orleans, Sea Level 2100 SSP5



Geospatial Climate Intelligence Dashboard
UNESCO Case Study



Financial Impact - Flood 2025-2050



Frequency & Severity - Hurricanes

Note: the plots are illustrative examples

Financial Loss Assessment Inputs

1. Exposure

Exposure data provide info of assets' locations, values, and characteristics.



2. Hazard

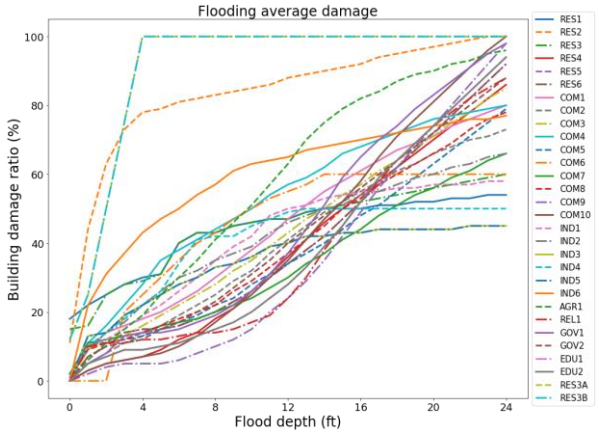
Hazard layers describe event frequency and severity of current and future years under various climate change scenarios.



New Orleans, Sea Level 2100 SSP5

3. Damage Function

Damage functions describe the relationship of damage level and hazard severity. Damage functions are asset and hazard specific.



Unifying Framework for Development and Evaluation

Despite increasing recognition of physical climate risk during the past decades, **many businesses have only recently started to account for its effects on their operations**. Consequently, climate risk modeling has become an integral component of risk management.

Climate impacts modeling poses multiple challenges: spatial resolution variations, lacking historical observational data, and alignment with model objectives and regulatory compliance.

Unfortunately, there is **no uniform framework or evaluation procedures** for climate hazard models development. This lack of standardization is particularly pronounced in the commercial sector due to inability to peer review proprietary models.

In response, we designed a 4-stage framework:
- pre-development (data and methodology scoping)
- development (implementation)
- post-development (scientific analysis)
- production assessment.

This evaluation framework can assist the climate risk commercial sector by improving models' reliability and applicability and facilitating development of holistic and shareable assessment procedures.

This approach has already been applied to development of over 12 hazard models at PwC US, offering valuable insights to businesses across various sectors.

Hazard Modeling Pipeline

Data and methodology scoping

Selecting climate data, considering:
- Reliability
- Scientific consensus
- Client goals
- IT infrastructure and analysis capabilities

Preliminary analysis:
- Licensing & collecting data
- Assessing data integrity, completeness, and quality
- Building & testing the in-house modeling workstream

Implementation

Code and implementation reviews:
- Analyzing methodology/algorithm
- Assessing model implementation
- Reviewing code quality

Back-testing:
- Collecting historical observations
- Evaluating against observations: confirming similar events/signals within the underlying reanalysis data

Scientific analysis

Benchmarking:
- Identifying credible hazard maps (scientific journals, government publications)
- Evaluating the overall pattern of present-day hazard

Evaluating the climate change impacts:
- Identifying scientific studies representing future changes in a peril
- Conducting a qualitative or quantitative comparison

Production assessment

Spatial consistency checks:
- Confirming spatial extent consistency and completeness
- Identifying issues and potential solutions

Final inspections:
- Identifying temporal and spatial outliers across hazard layers.
- Visual inspections confirming that client-ready layer requirements are met

Framework's Adjustments and Outcomes

- The designed 4-stage framework constitutes a foundation and is applied to each climate hazard assessment.
- Specific peril-related details are defined using in-house specialists who evaluate and confirm scientific and conceptual integrity, their readiness and fit for purpose.

✓ Climate data assessment is crucial for confidence in its reliability. It supports models' reputation and empowers consumers to help make informed decisions, facilitating more efficient resource allocation in the broader economy.

✓ This evaluation framework helps to standardize data collection, model development and production. Enhanced data comparability can boost confidence for both investors and consumers. In addition to providing high-quality transparent climate risk data, it promotes regulatory alignment.

This assessment framework helps to:

- make high-quality and transparent climate risk data,
- confirm model scientific and conceptual integrity, readiness and suitability for intended purposes,
- foster regulatory alignment.

Case Study: Heat Stress – Hazard model development

Among the direct climate risk impacts are **increasing global temperatures** including **heatwaves** and **chronic temperature increases**. Combined with high humidity it significantly affects human health, labor productivity, and infrastructure. Heat stress is a leading cause of climate-related mortality, impacts productivity, illness, electricity demand, and even crime [1].

Heat Stress Hazard Model

Our Heat Stress model uses the wet bulb globe temperature (WBGT) to calculate the effect on non-air-conditioned labor. This is done historically (1970−2014), and through the 21st century under different climate scenarios. WBGT captures the heat and humidity impact on people in temperature-exposed outdoor or non-air-conditioned environments.

Combining climate data, WBGT, and in-house research the model quantifies impacts under future climate conditions. Additional metrics (e.g., number of days per year above different WBGT) are further derived. This provides a fundamental understanding of a location's baseline/present-day hazard score (Figure 1) and its projected change.

Model Data Sources

Develop and evaluation of the model is based on three data types:

- "Reanalysis" blends 1979−2020 observational (weather stations and satellite) and weather model data for a global climate uniform view.
- Historical: downscaled, bias-corrected climate model 1979−2015 data (e.g., temperature and humidity).
- Future: downscaled, bias-corrected climate model 2015−2100 projections under various scenarios.

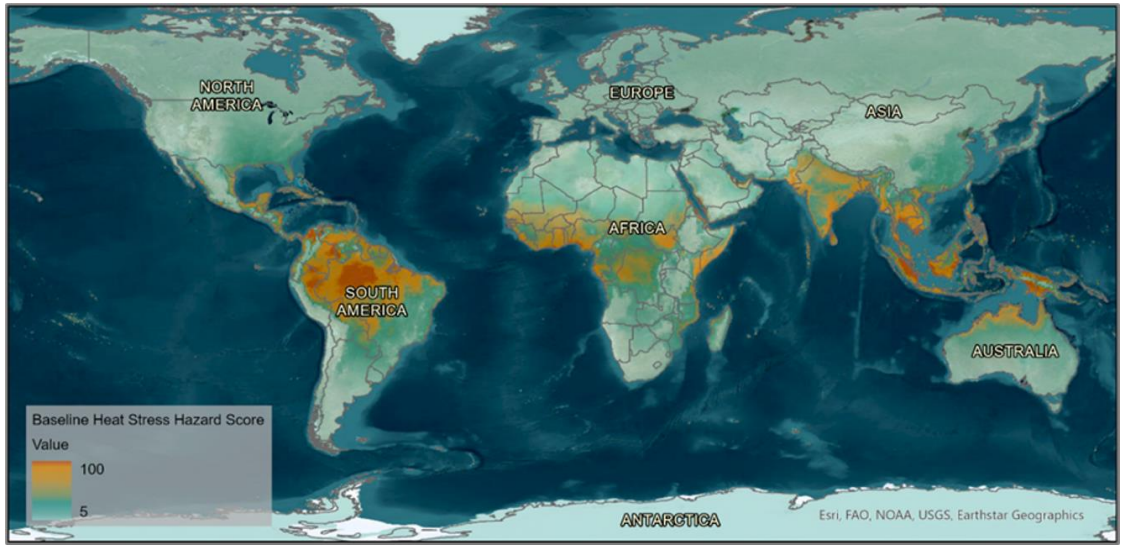


Figure1. Baseline heat stress score following the described methodology; powered by ESRI

Case Study: Heat Stress – Implementation assessment

Comparison of reanalysis data and Heat Stress Model over a baseline period (1979-2014)

Figure 2 demonstrates a good match between the reanalysis (a product closely aligned with real-world observations) and the model with respect to the metric measuring the mean annual number of days with WBGT above 25ºC over the historical period (1979−2014).

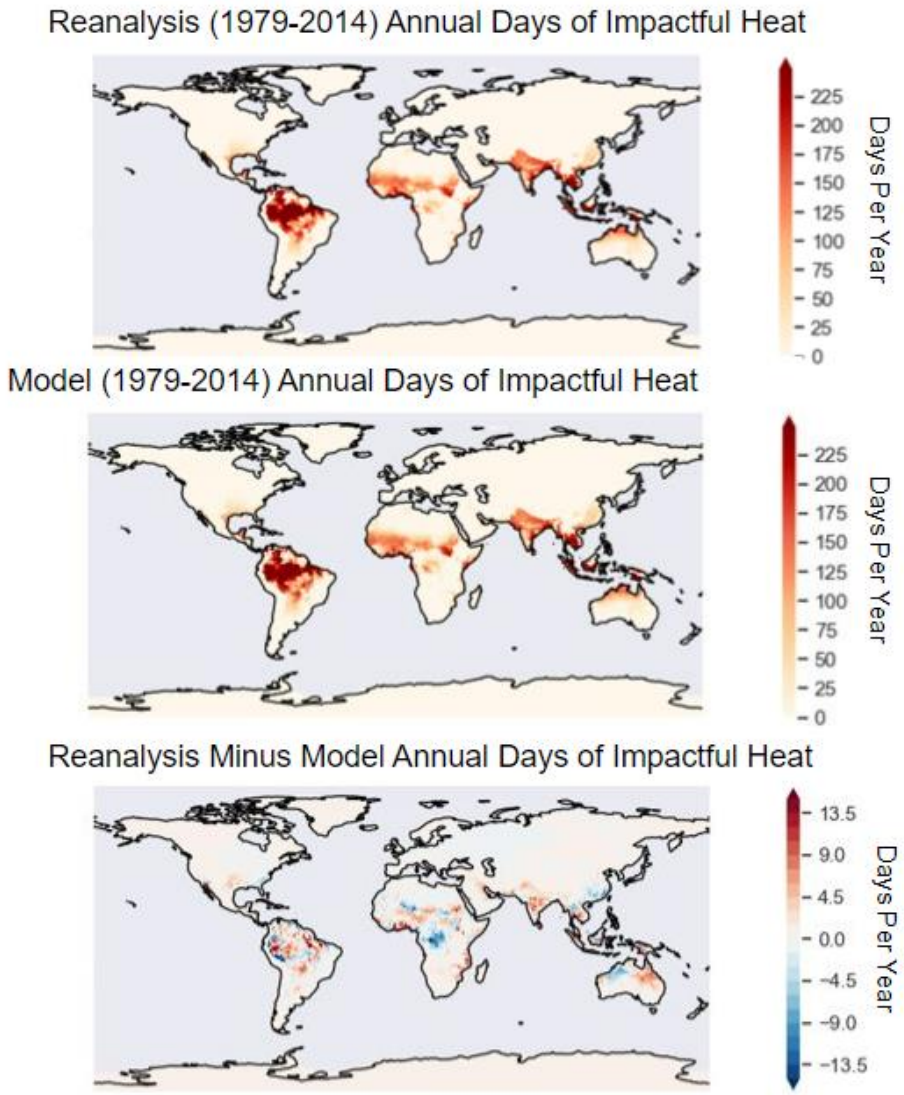


Figure2. The mean annual number of days with WBGT above 25ºC over the historical (1979−2014) period.

- Top panel shows reanalysis
- Middle panel shows the Heat Stress model over the baseline period
- Bottom panel shows the difference between reanalysis and the Heat Stress model

Case Study: Heat Stress – Implementation assessment

Back-Testing Using Historical Events

A famous event, often referred to as the 1995 Chicago Heatwave [2], which spanned most of the US Midwest was selected.

Figure 3 shows it clearly identified using WBGT calculated from the reanalysis data used in development of the Heat Stress model. The anomalies are relative to the historical average of July conditions, which are already hot in this region and time of the year. The Heat Stress model's reanalysis data show a jump in WBGT at the heatwave onset (July 12) and correctly identify peak conditions in Chicago on July 13−15. The WBGT daily mean in Chicago in the Heat Stress model's reanalysis data approached 85ºF, exceeding dangerous heat stress thresholds.

The event's spatial, temporal, and impact aspects are well-captured in the reanalysis data used in the model development.

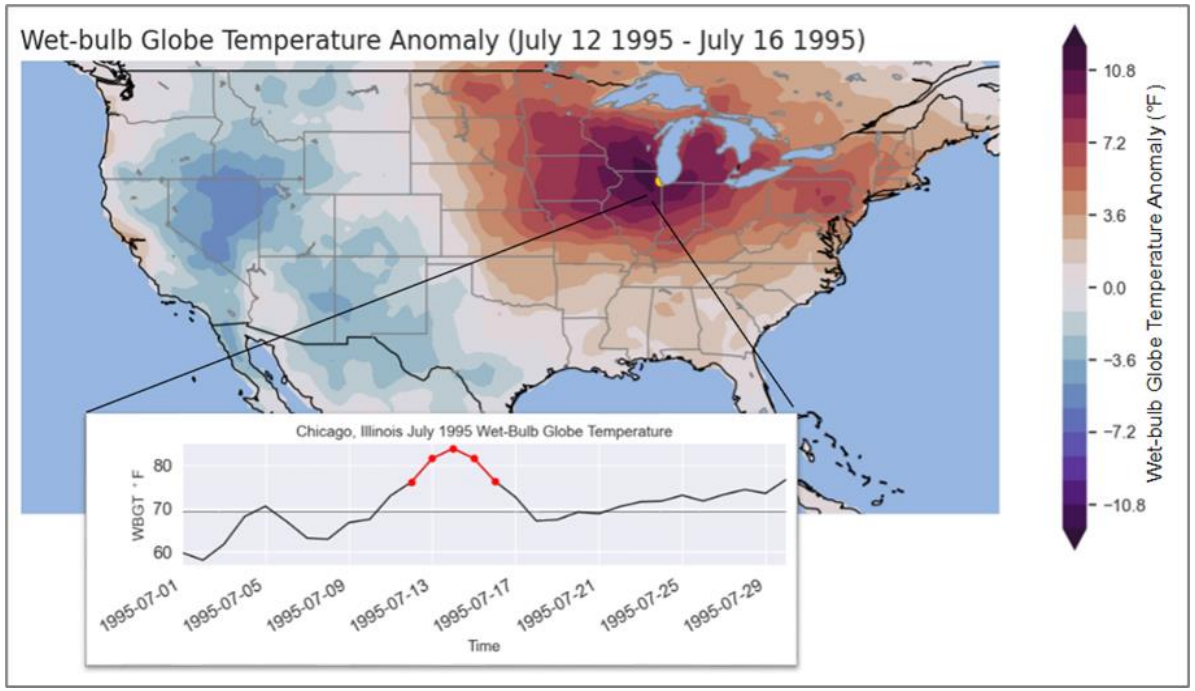


Figure3. WBGT during the July 1995 Chicago heatwave in the reanalysis data. The spatial map shows the WBGT temperature anomaly (relative to typical July conditions in 1979−2014). The anomaly is averaged over the period from July 12 to July 16, 1995. Note the very large (> 10ºF) anomaly centered on the Chicago area.

The break-out plot shows the daily WBGT time series in Chicago, Illinois, during the heat wave. Days identified in red clearly demonstrate dangerous WBGT levels. The horizontal line indicates Chicago mean July temperature.

Case Study: Heat Stress – Benchmarking the hazard level

Figure 4 compared the Heat Stress model results to a study [3], which examines potential heat stress impacts under various climate scenarios.

The comparison was qualitative due to differences in the input data, heat stress measures, and future scenarios' categorization.

Overall, a remarkably good agreement is shown, indicating that the Heat Stress model's heat stress global magnitude, spatial pattern, regional distribution, and temporal changes are in line with the leading science.

In a few regions (e.g., northwestern Africa or the Arabian Peninsula interior) some differences were observed. The analysis concluded they are likely due to differences in the precise formulation of "heat stress" by different indices. Given that the model uses WBGT, which is the leading metric for impact studies, the differences were acceptable.

Assessment for other periods and heat thresholds was conducted with results being similarly strong and showing good agreement between the model and published results.

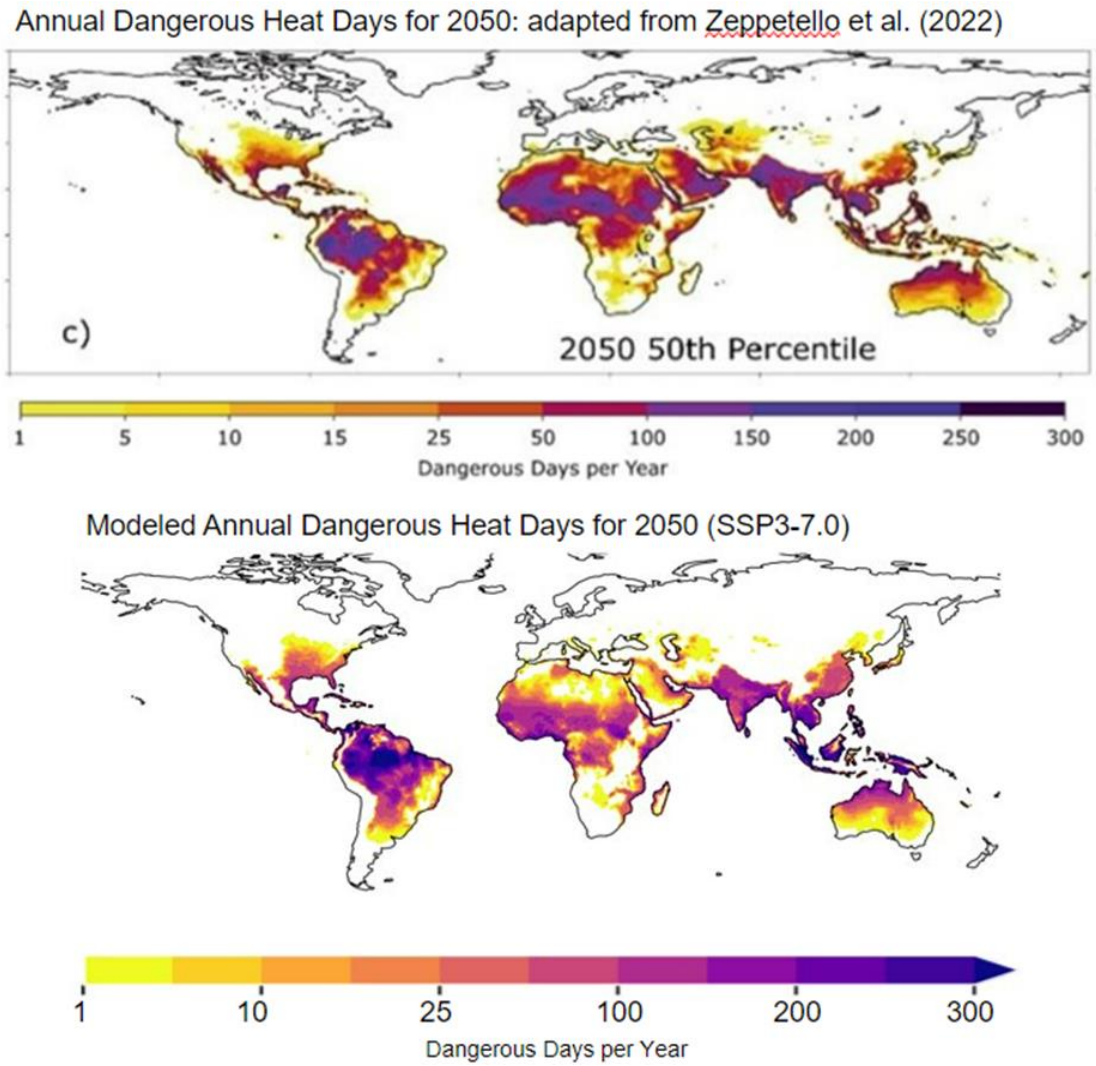


Figure4. The mean annual number of "dangerous" heat days in 2050 in a [3] (Zeppetello et al. 2022; top) and the Heat Stress model (bottom).

Hazard Modeling Methodology

Our methodology utilizes observed historical data and leading climate projections to calculate current and future hazard intensities — at varying levels of granularity and time horizons.

1) Gather and process historical and reanalysis data

- Publicly available data, including station-based, global gridded reanalysis, satellite, and more, for temperature, precipitation, and wind speed-related observations.
- Weather peril data gathered at a local level, cleansed, analyzed for frequency & severity, and aggregated.

2) Incorporate climate projections using CMIP6/ISIMIP framework

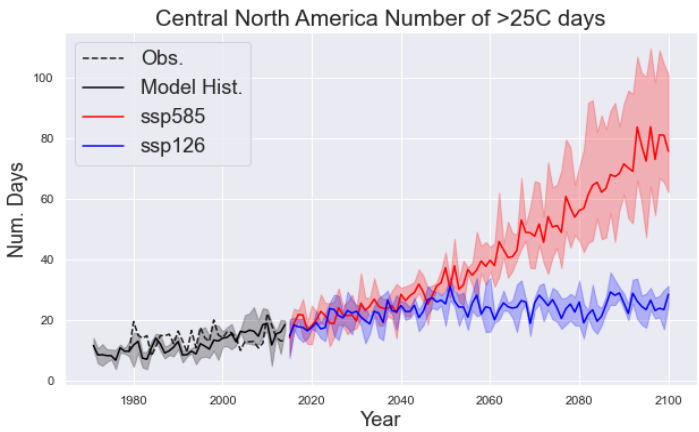
- Levering scientific models under the CMIP6 framework (*Coupled Model Intercomparison Project 6*).
- Several global climate models are considered to provide a reliable understanding of the future projections.
- Data gathered for historical and future scenarios in five year steps.

3) Combine historical data with climate projections to downscale the latter and assess future risks

- Downscale global climate models' data.
- Calculate representative climate driven changes.
- Assess and analyze model with real-world data.
- Project future extreme events risks.

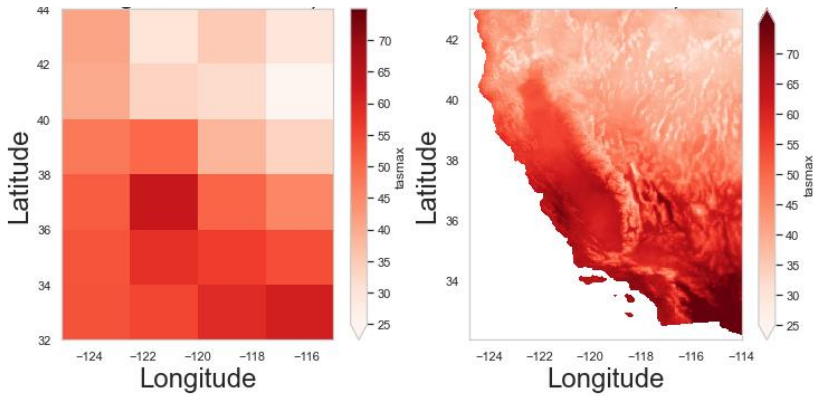
Wind Storm events, 1980-2020





Maximum Temp
Original Resolution

Maximum Temp
After Downscaling



Note: the plots are illustrative examples

Discussion

Thank you

alexander.andrianov@pwc.com



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